

# Electrochemical Industry

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## Electrochemical Industry

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## GREETING:

Notwithstanding the great proportions which the applications of electrochemistry have assumed in the United States, and the valuable contributions which here have been made to the science and to the art, this vigorous and rapidly-expanding branch of national industry has thus far lacked a journalistic exponent. That a field exists in this country for a journal devoted specifically to the science and applications of electrochemistry appears to be clearly indicated by the fact, among others, that no less than six such periodicals are published abroad, namely, three in Germany, two in France and one in England. To supply this vacancy will be the object of ELECTROCHEMICAL INDUSTRY, and it confidently hopes to be accorded in its endeavors the co-operation of all interested in the advancement of the science and the art.

It is the purpose to make this journal an authoritative exponent of electrochemical science and its various applications, and to this end the aid will be secured, so far as possible, of the leading authorities of the world in electrochemistry. In accordance with the fruitful policy of the best class of American technical journalism, the plan of the publication is to cover the field so broadly that its pages will satisfy in the most complete manner possible the needs of all interested, whether in the science or in the art of electrochemistry. Unhampered by precedent in its specific field, it will be conducted along the most advanced lines of modern technical journalism, while at the same time adhering to the honored traditions which have given such an enviable character to the higher class of the American technical press.

Owing to the considerable space allotted to the electrochemical industries of Niagara in view of the coming meeting there of the American Electrochemical Society, this initial issue is somewhat circumscribed in the scope of its contents. Among the distinctive features represented, however, we beg to call attention to the value of the review of the electrochemical periodical literature of the world; the analysis of current electrochemical patents; the first section of a digest of all United States patents relating to electrochemistry (which hereafter will appear in larger installments); and the first of a series of articles treating from the standpoint of practice the chemical and electrical principles upon which electrochemical applications are based. We are happy to announce that several of the leading electrochemical authorities of the world have consented to become regular editorial collaborators, and each issue will contain an article from the pen of one of these. With the sincere desire that our columns may be worthy of the great industry they represent, we earnestly ask the aid of our readers where they may further the value of the journal to the art and the science; and we beg their indulgence where they may find us lacking, for any shortcoming will not be from want of devotion to the cause in which these pages are enlisted.

### THE NIAGARA MEETING OF THE AMERICAN ELECTROCHEMICAL SOCIETY.

The second general meeting of the American Electrochemical Society will be held at Niagara Falls from September 15th to 18th. While the Society is now only five months old, it has grown and has met with a success far beyond the fondest hopes of its most enthusiastic promoters. The inaugural meeting at Philadelphia will long be remembered by all who attended it; there was an unbounded enthusiasm displayed by all then present, there was a great variety of good papers, and for the first time in the United States electrochemical engineers and scientists came in close contact with each other. But however great the success of the Philadelphia meeting, the gathering at Niagara bids fair to be even more successful. The beauties of the Falls are ever fresh, and to the electrochemist Niagara reveals still other charms; for the first time several of the large plants of this principal center of the electrochemical industries of the world will open the doors of their workshops to the public. The programme shows again a large variety of papers on important and interesting subjects, and the presence of German and British electrochemists gives an international flavor to the whole affair. We think that the meeting will turn out a success stimulating alike to the young society and to the interests which it so splendidly represents.



### HYDRO-ELECTRIC POWER AND THE ELECTROCHEMICAL INDUSTRIES.

Perhaps the fullest statistical data on the electrochemical industries thus far published are given in a paper read by Dr. W. Borchers before the German Electrochemical Society in 1899. The capacity of all electrochemical plants of all the world at that time is given at 421,220 horse-power, of which 378,350 horse-power, or 90 per cent., is obtained from water-power. Though somewhat stale with reference to such a swiftly-advancing industry, these figures nevertheless serve to emphasize a fact brought out in Dr. Richards' valuable article and in the interesting communication by Mr. W. McA. Johnson, published in this issue, namely, that the electrochemical industries have been enabled to make such remarkably rapid progress in recent years through the availability of cheap electric energy generating from water-power. The development of industrial Niagara Falls is an object lesson in this respect.



The development of large water-powers for electrical purposes was first undertaken with a view to the transmission of the energy over considerable distances, and to reduce the line loss, which increases with the square of the current, the use of relatively low currents was involved or, in other words, the employment of high voltages. Thus for a time hydro-electric power development was associated with high voltages and low current. Somewhat unexpectedly, however, and particularly at Niagara, electrochemical industries began to develop in the immediate vicinity of water-power generating plants, and then a diametrically opposite requirement demanded fulfillment, namely, low voltages and large currents. The heat generated in a furnace increases with the square of the current, and in electrolytic work the output in a given time is directly proportional to the current used. Therefore, for both furnace and electrolytic work, it is obviously necessary to use as large a current as possible. But the lower the voltage the less the

power, which has given rise to the saying that in electrochemistry it is the volts that cost money and the ampères which bring money. While thus electrical engineering in long-distance transmission is essentially high-tension work, it is large-current work in electrochemistry. Special and peculiar engineering problems had to be solved in order to meet the requirements of electrochemical work, and in this connection we direct attention to the admirable article on transformers for electrochemical work, which we publish in this issue, from the pen of Mr. John S. Peck, the transformer designer of the Westinghouse Co.



The inherent engineering difficulties having been successfully overcome, it is but natural that the development of hydro-electric power stations should be rapid. There is every promise of even a greater rate in the future, and the development of electrochemical industries will unquestionably proceed at the same pace; for generating stations are anxious to obtain a uniform, continuous load, and to this end they cannot have better customers than electrochemical industries. Another consideration which will aid and accelerate the progress of industrial electrochemistry in this country is the abundance of valuable ores and minerals in the United States, and the relatively high value of the products to be obtained from the same. Dr. Borchers' statistics bear out this point very well. While the power available in electrochemical plants in this country in 1899 was 86,350 horse-power, or 20 per cent. of the total 421,220 horse-power of all the electrochemical plants of the world, yet the value of the products which can be produced by the 86,350 horse-power developed here per year is \$97,500,000, and the corresponding value of the products which can be produced in all the electrochemical plants of the world together is \$146,500,000; in other words, in these data the presumptive value of the output of the United States is 67 per cent. of that of the whole world. Richly endowed by nature, there can be no doubt that the United States will be the country par excellence of electrochemical industries. People have long enjoyed our beautiful mountains and waterfalls for aesthetic reasons. The electrochemist takes a deeper view; he thinks of the ores in the mountains and of the power in the waterfalls. He feels that here lies dormant the strength and the future of the electrochemical industry. In this sense the view of the Falls of Niagara on the front cover of the first issue of the first American electrochemical journal may be considered as symbolic.



### THEORY OF CONCENTRATION CELLS.

The paper on a "Novel Concentration Cell," read by Prof. H. S. Carhart at the Philadelphia meeting of the American Electrochemical Society, was bound to arouse general interest and animated discussion for two reasons: first, certain facts ascertained with his nickel cell apparently overthrow a theory of concentration cells which has been regarded as being well established, and which has, indeed, been looked upon as one of the most prominent achievements of the modern theory of solutions; second, Prof. Carhart not only attempts to refute an old theory, but gives at the same time the foundations of a new one. We are glad to publish in this issue some further results, obtained more recently by Prof. Carhart, and we may await with interest his paper to be read at the coming Niagara Falls

meeting of the American Electrochemical Society. Meanwhile, it may be of interest to give a concise review of the development of the theory of galvanic cells in general and concentration cells in particular, and to point out that which is new in Carhart's theory and to show its relation to older theories.

When, more than fifty years ago, Helmholtz published his famous paper on the conservation of energy, he made a brief attempt to give a theory of the galvanic cell, under the assumption that the total chemical energy disappearing during electrochemical action is changed into electrical energy; this gives at once a simple relation between the e. m. f. of a cell and the formation heat of the chemical processes in it. Wm. Thomson (now Lord Kelvin) studied this matter shortly afterward, in greater detail, and since then it has become the custom to call that simple relation Thomson's rule. It was found, however, later that the fundamental supposition upon which this rule is based, is not quite correct. In electrochemical actions we have not simply a change of electric energy into chemical energy and *vice versa*, but heat also takes part in the process. By applying the two principles of thermodynamics to the problem, it was found that a correction factor, due to the heat effect, had to be added to the Thomson rule; the modified rule is now generally called the Gibbs-Helmholtz equation.

In the meantime the attention of some investigators had been directed to the study of a special and very simple type of cell, namely, what we now call a concentration cell, i. e., a cell in which the total change of chemical or internal energy corresponds to a change of concentrations. Helmholtz was again the first who in 1877 attacked this problem on the basis of the principles of thermodynamics. He devised an ingenious reversible isothermic cycle in which the concentration cell is first discharged and then the concentration changes are made retrograde by means of isothermic distillation; by applying the principles of thermodynamics to the cycle, he found a relation by which the e. m. f. of a concentration cell can be calculated if the aqueous vapor pressure over the electrolyte is known as a function of the concentration of the electrolyte. A bold step forward was then made by Nernst in 1889. At first glance Nernst's theory appears to be something entirely new, but a more careful analysis soon reveals the fact that he uses the two principles of thermodynamics just in the same way as Helmholtz did, but while he does so, he also makes use of the very distinct assumptions of the electrolytic dissociation theory concerning the constitution of an aqueous solution, and also of some additional ingenious assumptions concerning the so-called solution tension at a reversible electrode. The results which Nernst obtained in this way are in general accord with Helmholtz's theory—naturally because they are based upon the same broad principles—but as Nernst uses suppositions of his own, his results go further; he obtains a very distinct mechanical illustration or model of what happens in a concentration cell, and he can then apply his results to galvanic cells in general. He localizes the sources of e. m. f. at the electrodes and the junctions of different concentrations or different electrolytes, and he resolves the whole electrochemical action in a galvanic cell into a mechanism of ions. His theory of concentration cells has been confirmed repeatedly by

measurements, until Prof. Carhart described his nickel cell, which seems to contradict Nernst's theory.

To understand and appreciate the recent work of Prof. Carhart, it is necessary to refer to an important paper published by him in 1900 in the *Physical Review*. Prof. Carhart starts from the correct idea that the Gibbs-Helmholtz equation represents our most assured and best-established knowledge of the relation between the electric, thermic and chemical quantities in an electrochemical system; he starts from this equation and makes an important step to elaborate it. Heat is either taken in or given out by the system, or both occur at the same time at different points of the system. This is the object of Prof. Carhart's investigations. He localizes the heat effect at the two electrodes and separates them; thus instead of one temperature coefficient of the e. m. f. in the Gibbs-Helmholtz equation, he gets a sum of two, referring to the two electrodes. This is evidently a step in the right direction; he accomplishes the result that at least part of the total action is localized; while Nernst obtains the same result to a far greater degree by theoretical speculations, Carhart does it by experiment. Prof. Carhart's modification of the Gibbs-Helmholtz equation is valid for any galvanic cell; but it can evidently be best tested by a concentration cell with very dilute solutions; for the change of internal chemical energy, corresponding to concentration changes in very dilute solutions, is practically zero, hence in such a concentration cell we have practically an exchange only of electrical and heat energies. This consideration has evidently led Prof. Carhart to take up the study of concentration cells. He has built up his nickel cell exactly as concentration cells are generally built up; he has two nickel electrodes in two solutions of nickel sulphate of different concentrations. This does not prove, however, that this is really a concentration cell in the sense of Nernst's theory. Nernst in developing his formula, assumes that in a concentration cell of this type, the metal goes into solution at the anode and is deposited upon the cathode. In the experiments published by Carhart there is nothing to prove that this really takes place in his nickel cell; indeed, we have good reasons to doubt it in view of the established fact that during discharge the current in the nickel cell flows from the concentrated to the dilute solution. For we would be led to the conclusion that during discharge the dilute solution becomes more dilute and the concentrated solution becomes more concentrated, and this would be in contradiction with the second principle of thermodynamics, which is used by Prof. Carhart himself for establishing his theory. Hence it is quite probable that the chemical action at the electrodes in the nickel cell is somewhat different; it may be that chemical energy is here changed into other forms of energy; then we would not be justified to call it a concentration cell, and there would be no contradiction with Nernst's theory. While the sensational disagreement with Nernst's theory would then disappear, the general important value of Carhart's work, as sketched above, would not be diminished. There is no doubt that by Prof. Carhart's general formula we will be enabled to get a deeper knowledge of what happens in a galvanic cell, without making any doubtful hypothesis, but simply by experimental work. The very interesting results obtained by Prof. Carhart with the Daniell cell are alone sufficient to prove the value of his theory.



### THE AMERICAN ELECTROCHEMICAL SOCIETY.

The American Electrochemical Society will hold its second general meeting at Niagara Falls, September 15, 16, 17, 18, 1902.

The mornings will be devoted to the reading of papers, and the afternoons and evenings to visits and social meetings.

Members and guests will register and receive their badges as soon after their arrival as possible. Badges will be given to all members in good standing and to applicants who have deposited their initiation fee. Special badges will be provided for guests, who must be introduced by a member.

*Monday morning, September 15th, at 9 A. M.*

Meeting of Board of Directors at International Hotel.

*Monday morning, September 15th, at 10 A. M., in the music room of the International Hotel.*

Reading and discussion of the following papers:

Francis A. J. Fitzgerald, Niagara Falls, N. Y.: "Note on Testing Carbon Electrodes."

Prof. J. W. Richards, Ph.D., Lehigh University, Bethlehem, Pa.: "Efficiency of Electric Furnace Operations."

P. G. Salom, Philadelphia, Pa.: "Additional Notes on Lead Reduction."

Alfred T. Weightman, Niagara Falls, N. Y.: "Cathodic Reduction."

Prof. Louis Kahlenberg, Ph.D., University of Wisconsin, Madison, Wis.: "Differences of Potential between Metallic Cadmium and Solutions of Cadmium Iodide in Various Solvents."

*Monday afternoon, September 15th, at 2.30 P. M.*

Inspection of power house of Niagara Falls Power Co. and visits to electrochemical works, to be arranged by the Local Committee, starting from the International Hotel.

*Monday evening, September 15th, at 7 P. M.*

Reception in the parlors of the International Hotel. A Ladies' Committee will co-operate.

8 P. M. Banquet for members and ladies, followed by a ball at the International Hotel.

*Tuesday morning, September 16th, at 9.30 A. M., in the Auditorium of Natural Food Co's Building.*

Reading and discussion of the following papers:

Prof. R. S. Hutton, Owens College, Manchester, Eng.: "The Fusion of Quartz in the Electric Furnace."

Marcus Ruthenberg, Philadelphia, Pa.: "Developments in Electrometallurgy of Iron and Steel."

Prof. H. T. Barnes, Ph.D., McGill University, Montreal, Can.: "Theory and Practice of Continuous Flow Calorimetry."

Carl Hering, Philadelphia, Pa.: "An Apparent Electrochemical Paradox."

C. J. Reed, Philadelphia, Pa.: "Some Phenomena of Electrolytic Conduction."

Prof. Henry S. Carhart, LL.D., University of Michigan, Ann Arbor, Mich.: "The Nickel Concentration Cell."

Prof. W. E. Goldsborough, Lafayette, Ind.: "Electrochemistry at the World's Fair, St. Louis."

*Tuesday afternoon, September 16th, at 2.30 P. M.*

Visits to works and places of interest, to be arranged by the Local Committees, starting from the International Hotel.

*Tuesday evening, September 16th.*

Special search-light trip on the Niagara Gorge Railway.

*Wednesday morning, September 17th, at 9.30 A. M., in the music room of the International Hotel.*

Reading and discussion of the following papers:

Arvid Reuterdaahl, Providence, R. I.: "The Electronic Hypothesis and Its Applications."

Prof. John Langley, Ph.D., Cleveland, Ohio.: "Electrochemical Polarization."

Hugh Rodman, Philadelphia, Pa.: "Storage Battery Invention."

Woolsey McA. Johnson, New Brighton, S. I., N. Y.: "The Electrolytic Dissolution of Soluble Metallic Anodes."

C. W. Volney, Ph.D., Keyport, N. J.: "On the Electrolysis of Sodium Nitrate and the Composition of the Developed Gases."

*Wednesday afternoon, September 17th, at 2.30 P. M.*

Excursion and picnic to Dufferin Islands in Queen Victoria Park. The house and grounds of the Niagara Falls Country Club will be open to members for golf, tennis, etc., and may be reached by trolley from the hotel.

*Thursday morning, September 18th, at 9.30 A. M.*

Reading and discussion of the following papers:

D. H. Browne, Cleveland, Ohio.: "Pumps and other Accessories in Electrolytic Plants."

Prof. G. B. Frankforter, University of Minnesota, Minneapolis, Minn.: Subject to be announced.

Titus Ulke, Sault Ste. Marie, Ont., Can.: Subject to be announced.

Several other papers are expected.

*Thursday afternoon, September 18th.*

Private visits to electrochemical plants by personal invitations.

After the above programme had been issued, the following three additional papers were announced:

Alfred H. Cowles, Cleveland, Ohio.: "A Unit of Quantity of Electricity for Use in Electrochemical Calculations."

Edw. R. Taylor, Penn Yan, N. Y.: "Some Further Advances on the Closed and Continuous-working Electric Furnace."

Prof. F. Haber, Ph. D., Karlsruhe, Germany: Subject to be announced.

Visits will be arranged to a number of the installations of special interest to electrochemists, as also to places of general interest. Badges will be necessary to entitle members and guests to the privilege of taking part in the visits and excursions.

### PROPOSED BRITISH SOCIETY OF ELECTROCHEMISTS.

For some time past it has been thought to be advisable to form an electrochemical society in Great Britain.

An informal meeting to discuss the subject was held on March 4, 1902, at which a committee consisting of the following gentlemen was chosen to consider the subject: J. Swinburne (the present president of the British Institution of Electrical Engineers), Dr. F. M. Perkin, Dr. Donnan, W. R. Cooper, S. Cowper-Coles and H. V. Simpson. This committee has held meetings from time to time at which the best methods of procedure have been carefully discussed. The question of working in conjunction with one of the existing societies has also been considered, and several societies have been approached on the matter, but the committee takes the view that such an arrangement is not likely, at any rate, for the present, to have the desired effect. They have come to the conclusion, therefore, that the society should be independent. Steps in the direction of organizing this society have just been taken.

It has been suggested that there be two classes of members: full members and associate members, the subscription fee being two guineas and one guinea respectively (i. e., about \$10 and \$5).

The honorable secretary of the committee is H. V. Simpson, Grosvenor Mansion, Victoria street, S. W., London, Eng.

We hope the society will be founded and will meet with great success.



## TRANSFORMERS FOR ELECTROCHEMICAL WORK.

By J. S. PECK.

**I**N electrochemical work the demand is ordinarily for a transformer capable of delivering extremely heavy secondary currents at widely varying voltages, and which shall have a construction sufficiently rugged to stand excessive overloads for short periods and to operate twenty-four hours per day without deterioration.

The transformer which has been almost universally adopted for this work is that known as the oil-insulated water-cooled type. The transformer proper is mounted in a case of boiler iron, which is filled with oil, with primary and secondary leads carried through the top of the case.

The function of the oil is to increase the insulation strength and to carry the heat from the active parts of the transformer, where it is generated, to the cooling surfaces.

Water is almost always used for cooling, but there are a number of different methods of utilizing it. Where the secondary conductors are very heavy they are sometimes made hollow and the cooling water circulated directly through the conductors. This method, while very effective in cooling the secondary winding, takes up valuable space within the transformer, gives a bulky conductor in which eddy currents may be set up and is difficult to make water tight.

Another method consists in pumping the oil from the transformer case to an elevated cooling tank, where it comes in contact with water coils, is cooled and then allowed to circulate by gravity through the transformer.

The system in most common use, however, consists in placing the water-cooling coils within the transformer case below the surface of the oil. This brings the cooling coils into intimate contact with the oil, making a most efficient method of cooling, and one requiring the minimum amount of cooling apparatus and attention.

The design of a transformer for extremely heavy currents involves a number of interesting problems, a full appreciation of which requires a considerable knowledge of electrical engineering.

When a current of electricity flows through a circuit, a magnetic field is set up; if the current is alternating, then the field alternates also and induces a voltage in the circuit opposed or counter to the impressed voltage. The effect of this counter voltage is to cause an increased drop of pressure in the circuit, so that the voltage delivered to the load may be very much less than would be obtained with direct current where the only drop is that due to ohmic resistance.

The amount of this counter voltage increases directly with the current in the circuit and with the frequency or rate of alternations. It also increases as the distance between conductors is increased, and varies somewhat with the size and shape of the conductors themselves.

In electrochemical work, where the volume of current is large and the voltage low, the conditions are favorable for the production of a high percentage of counter voltage, and unless special precautions are taken it may be, with full-load current, almost as large as the impressed voltage, leaving practically no pressure for forcing current through the load.

To reduce this counter voltage the secondary is divided into a large number of parallel circuits, placed side by side, and as near together as mechanical considerations will permit. Thus the current in any one circuit is kept down to a reasonable volume, the conductors are kept close together with a correspondingly reduced counter voltage.

Where a number of circuits are thus operated in parallel it is customary to have each circuit supplied from a separate coil in the transformer, and great care is necessary in the design of the transformer to obtain a symmetrical relation between primary and secondary windings, in order that the voltage induced in all the coils may be the same. If the voltage on the different coils is not the same, then the coil or

coils having the higher voltage will force a local current through the coil or coils of lower voltage, which will result in unequal and excessive heating in the coils.

Another element of danger in the design of apparatus for heavy currents is the stray field induced by the current in the conductors. For if this field cuts the large conductors, heavy local or eddy currents may be set up. This trouble is particularly apt to occur inside the transformer, and careful consideration must be given to it when a transformer is designed.

Since the counter voltage induced in a circuit depends upon the rate of alternations, it is obviously desirable to have as low a frequency as possible. For most of the electrochemical work done up to the present time a frequency of 3,000 alternations per minute (or, in other words, 25 full periods per second) has been used, as low a value as is considered feasible for general power distribution. In certain cases, however, where extremely heavy currents at low voltage have been demanded, difficulty has been experienced in keeping down the counter voltage to anything like a reasonable value, and it is probable that for certain electrochemical work a frequency considerably lower than this will be adopted.

In electrochemical work the great majority of transformers are supplied from primary mains, the voltage of which cannot be varied, and as one of the requirements for this work is that the transformer shall deliver a variable secondary voltage, it is necessary that some means of varying the voltage be provided in connection with the transformer itself.

There are two general methods of accomplishing this variation:

1st. By changing the ratio between the primary and secondary turns.

2d. By placing in the primary or secondary circuit of the transformer an auxiliary transformer, having a variable voltage ratio, the voltage of which may be added to or subtracted from that of the main transformer.

Of the two methods the first is ordinarily the simpler and cheaper, and will be first considered.

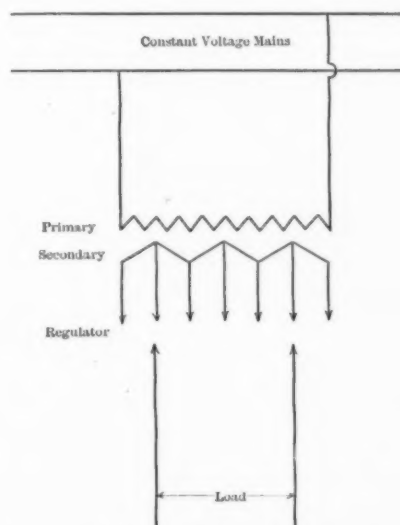


FIG. 1.—REGULATOR IN SECONDARY OF TRANSFORMER.

Fig. 1 shows diagrammatically the primary and secondary windings of a transformer. From the secondary winding a number of taps are brought out, so that by connecting to different taps a varying number of secondary turns may be obtained. If the transformer is supplied from 2,000-volt mains and there are 200 turns in the primary winding, then there will be upon every turn in the transformer 10 volts. If the secondary has 10 turns, the total voltage induced in this winding will be 100. If one of the secondary terminals be moved so

that there are but 9 turns between the two terminals, then but 90 volts will be delivered. If 8 turns are included, then 80 volts will be delivered, etc.

With large transformers there are a number of objections to this method of varying the number of secondary turns. One is that the current in the secondary is so large that it is difficult to change from tap to tap without cutting off the current from the transformer. Another is that the voltage steps obtained are usually too large a percentage of the total voltage to be permissible.

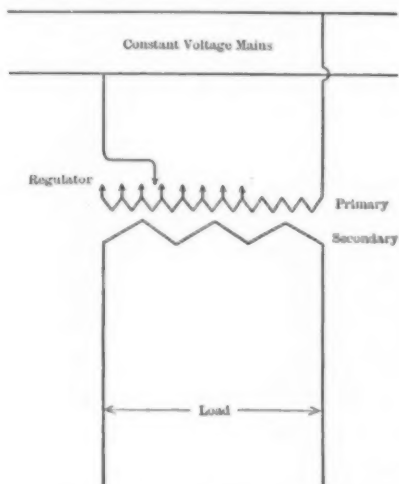


FIG. 2.—REGULATOR IN PRIMARY OF TRANSFORMER.

To avoid this difficulty a modification of this method, shown in Fig. 2, is used. Here the taps are brought out from the high-tension winding and means are provided for stepping one line terminal from tap to tap.

If, as before, the primary voltage is 2,000, the primary turns 200 and the secondary turns 10, then with the whole primary winding in there will be 10 volts per turn and 100 volts on the secondary. If half the primary winding be cut out, so that there remains but 100 turns, then there will be 20 volts per turn and 200 volts on the secondary. If the primary voltage is impressed on 150 turns, there will be  $13\frac{1}{3}$  volts per turn and 133 volts on the secondary winding.

As the primary winding has many more turns than the secondary, it is possible to obtain much smaller steps than when the change in turns is made on the secondary. The primary current is small compared with the secondary, and may be usually handled without serious difficulty.

For changing the line terminal from one tap to another, a regulating dial is required. If the output of the transformer is small, so that the primary current is low and the voltage between taps not excessive, then a dial similar to that shown in Fig. 3 may be satisfactorily used. If, however, the current is very heavy or the volts between steps excessive, it is necessary to supply a more substantial type of regulator. Fig. 4 shows a switchboard type of regulator designed for handling heavy currents, with several hundred volts between steps.

The connections for this regulator are shown in Fig. 5. When switch No. 1 is closed, the line terminals are connected directly across the total winding. If it is desired to cut out turns to raise the secondary voltage, the method of procedure is as follows: switch No. 2 is closed, switch No. 1 is opened, switch No. 3 is closed and switch No. 2 is opened. When switches No. 1 and No. 2 are closed at the same time, a resistance "R" prevents a short circuit and excessive flow of current between the points 1 and 2 on the transformer winding. The same condition exists when switches No. 2 and No. 3 are closed at the same time. When switch No. 3 is connected to the line and all others open, it is evident that the line

terminal X is connected directly to the transformer winding at 3, thus cutting out entirely turns between 1 and 3.

On this particular regulator the switches were operated by hand one at a time. It is, however, desirable to have the different switches actuated by a common shaft driven by a crank at the end of the board, and such an arrangement may be easily adapted to a regulator of this type. The great merit in this form of regulator is that the construction is exceedingly simple and substantial, so that there is little danger of the

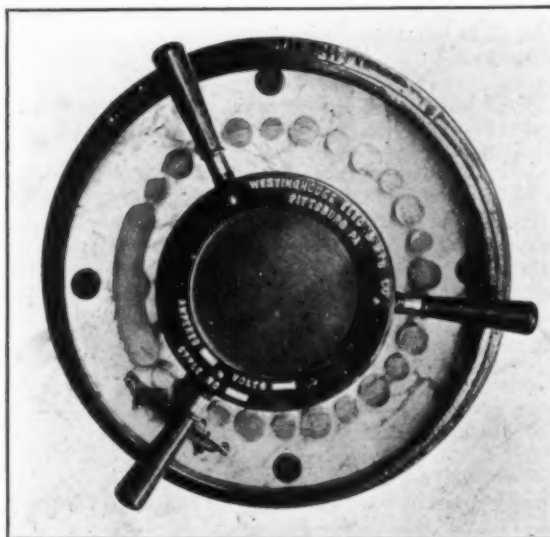


FIG. 3.—REGULATING DIAL.

troubles developing in this regulator which are common to many regulators of the dial type.

The second system of regulation, which consists in placing a regulating transformer in series with the primary or secondary of a transformer, may be operated in a number of different ways.

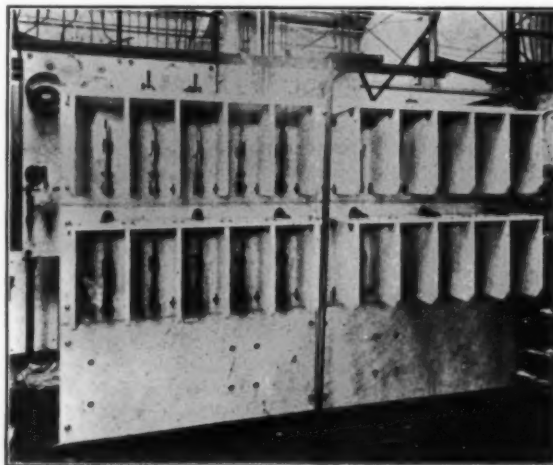


FIG. 4.—SWITCHBOARD TYPE OF REGULATOR.

Fig. 6 shows a regulating transformer placed in the secondary of the main transformer. To vary the voltage of the regulating transformer the number of turns in the secondary are changed as indicated in the diagram. When the voltage of the regulating transformer is in such a direction as to assist that of the main transformer, the voltage applied to the load will be the sum of the secondary voltage of main and regu-

lating transformer. When the voltage of the regulating transformer opposes that of the main transformer, the voltage on the load will be equal to the difference between the voltage of the main and that of the regulating transformer.

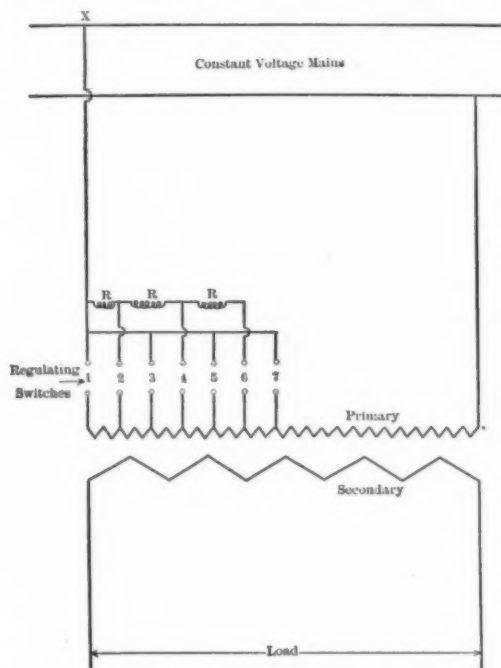


FIG. 5.—CONNECTIONS OF REGULATOR.

The objection to this particular method lies in the difficulty of handling, on any type of regulator, the heavy currents in the secondary circuit; also to the fact that the voltage steps obtainable are ordinarily larger than is permissible.

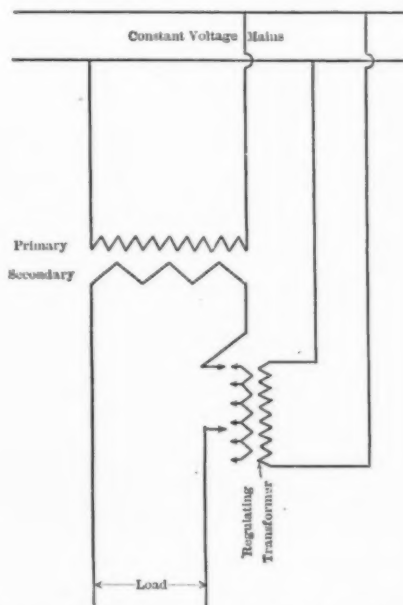


FIG. 6.—REGULATING TRANSFORMER IN THE SECONDARY OF THE MAIN TRANSFORMER.

Fig. 7 shows the same type of regulating transformer, but connected in the primary circuit. When so placed the currents to be handled are much smaller and finer adjustments in voltage may be obtained.

Fig. 8 shows a method of regulation in which the ratio of primary and secondary turns in the regulating transformer is maintained constant, the voltage being varied by changing the voltage impressed upon the primary of the regulating trans-

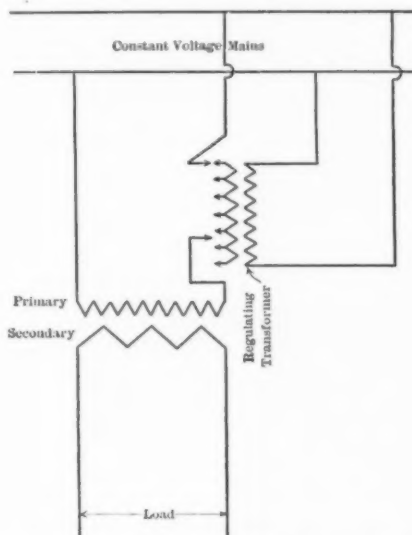


FIG. 7.—REGULATING TRANSFORMER IN THE PRIMARY OF THE MAIN TRANSFORMER.

former. The variable voltage for the regulating transformer is obtained from an auxiliary "auto" or single-coil transformer. With this scheme the current in the regulating circuit may be kept down as low as desired by choosing a suitable voltage for the primary of the regulating transformer. Fig. 8 shows the regulating transformer in the secondary circuit, but it could obviously be as well placed in the primary circuit.

Fig. 9 shows a modification of the method shown in Fig. 8. Here the primary of the regulating transformer is supplied

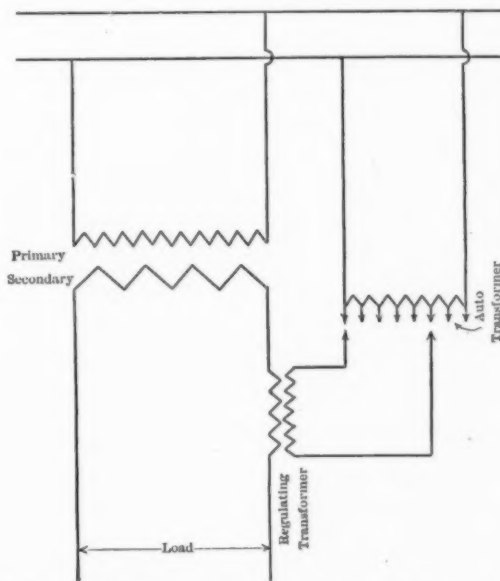


FIG. 8.—METHOD OF REGULATION BY MEANS OF A REGULATING TRANSFORMER AND AN AUXILIARY AUTO-TRANSFORMER.

from taps which are brought out from the primary winding of the main transformer, thus doing away with the necessity of the auxiliary auto-transformer.

In all the methods of regulation which have been described



the variation in voltage is obtained by the step-by-step method, although the main circuit of the transformer is never opened, so that current is never cut off from the load. In certain classes of electrochemical work it is necessary that the voltage be varied gradually, moving by steps. Where this is required, it is customary to place in series with the primary or secondary winding of the main transformer the secondary of an induction regulator (see Fig. 10). This regulator is a form of trans-

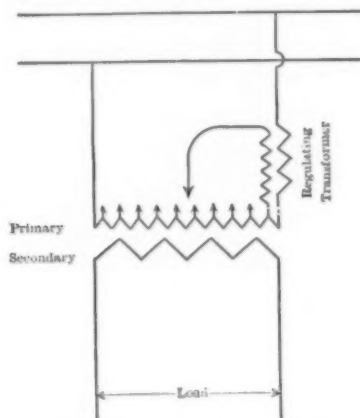


FIG. 9.—MODIFICATION OF THE ARRANGEMENT OF FIG. 8.

former so arranged that the primary and secondary windings may be moved inductively with relation to each other, so that by a proper movement the secondary voltage of the regulator can be varied from 0 to a positive or negative maximum, the change in voltage being at a perfectly uniform rate. The objection to this form of regulator is its high cost and low efficiency as compared with regulators of the step-by-step type.

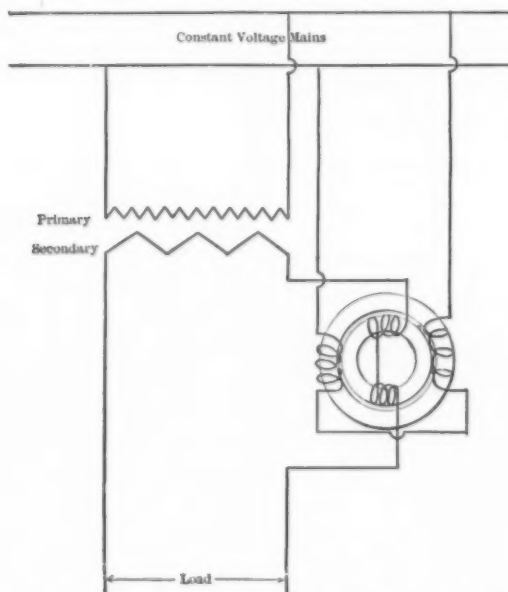


FIG. 10.—METHOD OF REGULATING THE VOLTAGE AT A UNIFORM RATE.

To say that the construction of transformers and regulators for delivering heavy currents at variable voltages has kept pace with the growth of the electrochemical industry is sufficient to indicate the development along this line. But such is the case, and the limit to the amount of current or range in voltage will not be set by the transformer designer, but rather by commercial considerations and the demand of the electrochemical industry.

## IONIC VELOCITIES IN LIQUID AMMONIA SOLUTIONS.\*

By PROF. EDWARD C. FRANKLIN AND HAMILTON P. CADY.

Measurements of the electrical conductivity of salts dissolved in liquid ammonia have shown that such solutions carry the current with remarkable facility, surpassing in this respect even aqueous solutions themselves. As an example may be cited the case of potassium nitrate, which in solution in liquid ammonia shows the following conductivity as compared with aqueous solutions at the same concentrations:

Dilution	Molecular Conductivity of KNO <sub>3</sub> in	
	NH <sub>3</sub> at -33°	H <sub>2</sub> O at 18°
1.....	.....	75.2
10.....	88.0	103.7
100.....	138.5	114.0
1,000.....	245.0	119.0
10,000.....	319.0	122.0
50,000.....	337.0	121.5
70,000.....	338.0	.....

Other salts show an entirely similar behavior.

The rapid increase in the molecular conductivity with dilution and its final high value are interpreted as meaning that in the more concentrated solutions the salts are dissociated to a much smaller degree in ammonia than in water, and that to complete the dissociation in ammonia solutions the dilution must be carried much higher than is necessary in the case of aqueous solutions. Referring to the table given above, it will be seen that while dissociation is well on towards completion in water solutions at a dilution of 1,000, in ammonia solutions, on the other hand, the dilution must be carried up to somewhere between 10,000 and 50,000 in order to bring about the same degree of dissociation.

Now, if liquid ammonia solutions are to meet the requirements of the theory of electrolytic dissociation, it is necessary to assume that the ions in this solvent travel at a much greater speed than they do in aqueous solutions. It was to determine by direct measurement the velocity with which a number of anions and cations travel in liquid ammonia that the present investigation was undertaken.

The method used consisted, for example, in the case in which the velocity of a cation was to be measured, in noting the speed with which the boundary between two solutions containing a common anion traveled up a graduated tube. The solution containing the cation whose speed was to be measured was superimposed upon a solution containing a heavier and slower cation. The velocity with which the meniscus moves up the tube is conditioned only upon the faster cation, the slower, heavier cation serving merely as an indicator. The details of the somewhat complicated piece of apparatus, together with the complete data, will be published in the near future.

The results obtained are as follows, compared with the speeds of the same ions in water solutions:

	Velocity in cm. per sec. per volt.	
	in NH <sub>3</sub> at -33°	in H <sub>2</sub> O at 18°
Ammonium .....	0.00133	0.00055
Potassium .....	0.00167	0.00057
Sodium .....	0.00132	0.00035
Silver .....	0.00103	0.00046
Nitrate ion.....	0.00166	0.00053
Bromine ion.....	0.00168	0.00059

These values are in very fair agreement with the conductivity measurements of Franklin and Kraus.

\* Abstract of a paper read at the Pittsburg meeting of the A. A. S., July, 1902.

### CONTRIBUTIONS TO THE THEORY OF CONCENTRATION CELLS.\*

BY PROF. HENRY S. CARHART.

The two classes of simple concentration cells are:

1st. Two electrodes of the same metal immersed in a solution of a salt of this metal, the density of the solution at the two electrodes being different.

2d. Two electrodes consisting of an amalgam of the same metal, the concentration of the metal in the amalgam being different at the two electrodes, both immersed in a solution of a salt of this metal.

The usual Nernst formula for the electromotive force of a concentration cell requires that the direction of the electromotive force through the cell shall be from the dilute to the concentrated solution. Considerations derived from the thermo-electromotive force at the contact of metals and their salts, led the author to construct a concentration cell of the first of the above classes in which the direction of the electromotive force within the cell is from the concentrated to the dilute solution. It consists of nickel immersed in a solution of nickel sulphate or chloride.

In the Nernst formula the electromotive force is proportional to the absolute temperature. This suggests a thermal origin for the electromotive force of a concentration cell. From this point of view *concentration cells are devices for converting the heat of their surroundings into electrical energy.*

The same conclusion is reached when one considers the Helmholtz equation for the electromotive force of a voltaic cell. It may be written

$$E = -\frac{H}{q} + T \frac{dE}{dT}$$

$H$  is the heat equivalent of the chemical reactions. If the temperature coefficient is positive, the energy given out by the cell is greater than the chemical energy transformed, or the element tends to cool and to take heat from its surroundings. In general, as the author has shown in another paper, heat is absorbed on one side of the cell and is generated on the other side. In the Daniell cell the two almost exactly counter-balance each other.

If the Helmholtz equation is generally applicable, then where there are no chemical reactions to furnish energy, the only source of electrical energy is heat. The electromotive force is then obviously thermal. From this point of view the nickel concentration cell does not constitute an exception, save that the thermo-electromotive force is directed from the metal to the solution of its salt, while with zinc, copper, silver, cadmium, etc., it is the other way.

These facts are not sufficient to explain the electromotive force of a concentration cell without the aid of another law, which the author has discovered, namely, the law of the increase of the thermo-electromotive force with the concentration of the solution, and of its decrease with the increase of the concentration of the metallic ion in the amalgam. Hence, the thermo-electromotive forces on the two sides of the cell do not balance each other, and the residual explains the electromotive force of the concentration cell. Curves were shown exhibiting the relation between thermo-electromotive forces and concentrations, both as regards solutions and amalgams. Hence, both classes of simple concentration cells are explained by means of the thermo-electromotive forces at the contact between the electrodes and the solution.

Since the thermo-electromotive force increases with the concentration of the solution and decreases with the concentration of the ion in the amalgam, it should be possible to offset the one with the other. A single trial with zinc amalgam and zinc-sulphate solutions gave a cell with an electromotive force of only 0.0004 volt.

\* Abstract of a paper read at the Pittsburg meeting of the A. A. A. S. July, 1902.

The law of the increase of the thermo-electromotive force with the concentration of the solution explains two well-known facts about the Daniell cell:

1st. Its electromotive force increases with the density of the copper-sulphate solution and decreases with the increase in density of the zinc-sulphate solution. With these metals the thermo-electromotive force is directed from the solution to the metal. It is, therefore, clear that any increase in the concentration of the copper-sulphate solution must increase the thermal component of the electromotive force of the cell, and conversely with the zinc-sulphate solution. The only other explanation of this fact ever given is based on osmotic pressure.

2d. It is known that the temperature coefficient of the Daniell cell at ordinary concentrations is negative; that with concentrated copper sulphate, and zinc sulphate solution having a density of about 1.04, it becomes zero; with a still weaker zinc sulphate solution, the temperature coefficient is positive. This fact is readily explained when one remembers that the temperature coefficient of the cell is the resultant of all the thermo-electromotive forces at the several contacts. The one at the Zn-ZnSO<sub>4</sub> reduces the electromotive of the cell or tends to make the temperature coefficient negative. By reducing the concentration of the zinc sulphate solution this thermo-electromotive force is reduced till it is smaller than that at the copper plate, and then the temperature coefficient of the cell becomes positive.

### ELECTROCHEMISTRY AS AN ENGINEERING COURSE.

BY PROF. C. F. BURGESS, E. E.

The establishment of a four years' course in applied electrochemistry finds its justification in the marked development of the electrochemical industries and the consequent demand for men having a special training. The marked differences of opinion which have been expressed as to what electrochemical training should consist in, arises from differences of opinion as to what the product should be, whether an electrochemical engineer or an electrochemist.

The industrial development of electrochemistry has been the result of adapting former and well-known laboratory experiments to large-scale industrial practice more than to new scientific discoveries, and progress along this line will undoubtedly continue. Chemical manufacturing was a number of years ago considered best developed when the processes were so simple that no power was necessary to assist in the chemical reactions, but this condition has changed and the chemical industries are now pre-eminently power-using industries. This has been the result to a large degree upon the use of electrical energy either in the electrolytic cell or the electric furnace for producing chemical changes.

A knowledge of the properties of materials of construction and of the transformations, distributions and utilization of various forms of energy is, therefore, essential for an electrochemical engineer, and such knowledge can best be obtained in an engineering course, conducted along much the same lines that are followed in electrical, mechanical, or other engineering courses.

Something over a year ago the Engineering College of the University of Wisconsin established a four years' course with the object of furnishing such training, and designed in accordance with the idea that the electrochemical engineer should be primarily an engineer, with however a considerable knowledge of chemistry and chemical engineering subjects. The principal difficulty is that a great amount of laboratory work is necessary in connection with most of the required studies, and the amount of time which should be devoted to all of them is hard to crowd into a four years' course.

\* Abstract of a paper presented at the recent Pittsburg meeting of the Society for the Promotion of Engineering Education.

## PIONEERS OF ELECTROCHEMISTRY—I.

CHARLES M. HALL.

**C**HARLES M. HALL, inventor of the Hall process for producing aluminum, was born at Thompson, Geauga County, Ohio, on December 6, 1863. His father is a Congregational minister, and moving to Oberlin in 1873, young Hall attended the public schools there and later Oberlin College. At college he took the classical course, graduating in 1885. During the course he had one term of chemical study with Professor Jewett, and was so captivated with the subject that for nearly a year thereafter he experimented in the Oberlin laboratory, with the special object of finding an electrical method of commercially producing aluminum. The detailed history of these attempts is as follows:

Hall's experiment's were made with a galvanic battery as the source of his current, and a gasoline burner to heat his crucibles. His idea was that alumina was the cheapest aluminum compound, and that if he could find some easily-fusible salt which would, when molten, dissolve alumina, he might, by electrolysis, obtain from the bath aluminum and oxygen, just as copper and chlorine are obtained by electrolyzing an aqueous solution of copper chloride. His early experiments failed because of using clay crucibles, and it was not until he lined the crucibles with a mixture of ground gas-retort carbon and tar that he succeeded in producing the metal. This was on February 23, 1886. The solvent bath then used was cryolite, the double fluoride of aluminum and sodium.

In the summer of 1886 he went to Boston, where his brother, a clergyman, raised money to continue the experiments, power was rented and four months' work done with a small dynamo. The basic patent for the process, using for the solvent bath a double fluoride salt of aluminum and of a more electro-positive metal, was applied for on July 9, 1886. Much of the work at Boston was directed towards working the bath with copper anodes, which, indeed, work to some extent, by becoming oxidized superficially, but have since been proven decidedly inferior to carbon anodes. The finding of the best anodes to use in the bath consumed practically two years' time, and, meanwhile, the work at Boston was discontinued, after four months of effort.

Returning to Oberlin, in the fall of 1886, Hall stuck with dogged perseverance to his task of developing a commercial process. He constructed a large bichromate-sulphuric acid battery of 12 cells, each a gallon capacity, casting the zincs himself by melting down scrap zinc. He had no current-measuring instruments, but, working with small iron crucibles, 2 inches in diameter, carbon lined, obtained lumps of metal one-quarter ounce in weight, at a run. The work was carried on mostly with the use of potassium fluoride in the bath, instead of sodium fluoride. This bath is more easily fusible than the sodium bath, but is not so permanent, and, therefore, not so suitable for a continuous process. The results, however, were encouraging, and in December, 1886, Hall went

to Cleveland, where an uncle resided, in order to raise funds to work on a larger scale.

Negotiations with Cleveland capitalists lasted some six months, the principal stumbling block being the division of interests in the future commercial development of the process. Hall was willing to give a good share of his patent rights for funds to continue developing his process, but insisted on having at least one-fourth interest in the company organized to work the process. Meanwhile, the United States patent office declared an interference between Hall's application and that of Héroult, and this forced matters to a head, so that in the summer of 1887 Hall entered into an agreement with the Cowles Electric Smelting and Aluminum Co., under which Hall was to have electric current and facilities for experimenting at the Cowles works, at Lockport, N. Y., giving in return a six months' option on his process, in exchange for a certain fraction of the stock of that company. After six months the option was renewed for three months more, but at the end

of nine months the option ceased, without the company carrying it into effect. Mr. Cowles' statement of their reason for letting the process pass from their control is that the results, as far as they saw, were not sufficiently encouraging. Mr. Hall's statement is that he figured up that he then made aluminum at the rate of one pound per horse-power per twenty-four hours, but that the current at his command was so small that he would work many hours over a hot fire to make a few ounces of aluminum, and that all that was needed was to apply the process on a larger scale. We will go no further into this controversy, which probably never will be settled satisfactorily to all concerned, and so we merely state the two sides.

Romaine Cole, also employed at the Cowles works, undertook at this juncture to interest capital in the process. He interested Capt. A. E. Hunt and Mr. Mellon, the banker, of Pittsburg, and in August, 1888,

the Pittsburg Reduction Co. were organized, with a capital of \$20,000, and work on an installation being at once commenced, the company were turning out aluminum commercially by November, 1888.

Meanwhile, the interference in the patent office had been decided in favor of Mr. Hall, and the business was clear of incumbrance and entered on an era of continuous development.

In 1891 the plant was moved to New Kensington, 16 miles from Pittsburg, on the Allegheny River; in 1893 a contract was made with the Niagara Power Co. and the "upper works" started, using 1,800 horse-power, in 1895, and since increased to 3,600 horse-power. In 1896 the "lower" Niagara plant was started, using 3,500 horse-power, since increased to 6,500 horse-power. Since then the company have bought bauxite mines in Georgia and Arkansas, have started a 5,000 horse-power reduction plant at Shawinigan Falls, Quebec, and are commencing on a 10-acre plant at Massena, N. Y., which will utilize 12,000 horse-power.

In connection with these developments, Mr. Hall has invented several important improvements.



*Charles M. Hall*



## NIAGARA AS AN ELECTROCHEMICAL CENTRE.

### THE ELECTROCHEMICAL INDUSTRIES OF NIAGARA FALLS.

BY JOSEPH W. RICHARDS, PH.D.

*President of the American Electrochemical Society.*

THE second meeting of the American Electrochemical Society, inaugurated in Philadelphia, April 3d, of this year, is with the greatest propriety scheduled to be held at Niagara Falls, in September, of this year. Although Philadelphia may with right claim to be the birthplace of the American Electrochemical Society, Niagara Falls may with

No field in the whole range of the applied sciences is succeeding more signally, promising more attractively, or so pregnant with suggestions of future applications, than electrochemistry. In the hands of the masterful chemist, acquainted with the facts of chemistry and the needs of civilization, the uniting and decomposing powers of the electric current, its almost infinite control of chemical analysis and synthesis, the generation of inconceivable temperatures on a commercial scale and the methods it furnishes of torturing poor Mother Nature into new shapes and wringing from her new secrets, has

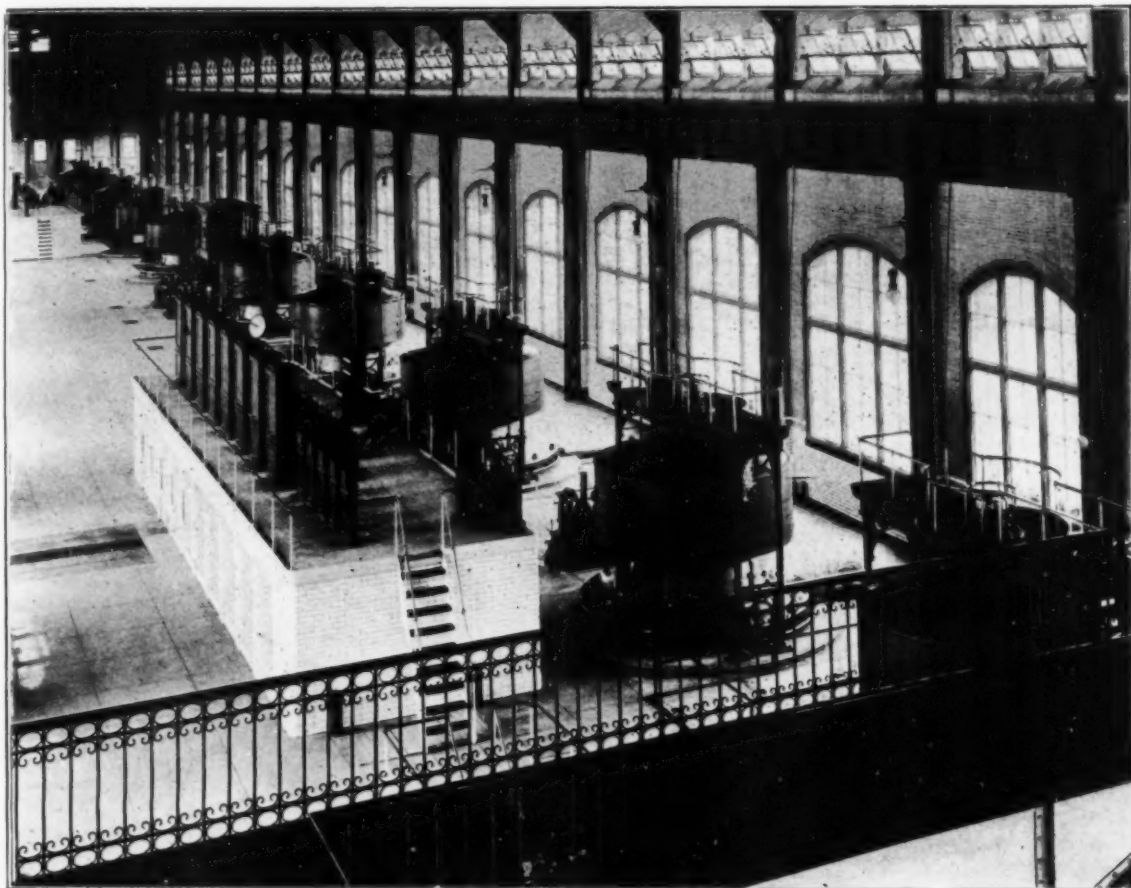


FIG. 1.—POWER HOUSE NO. 1, NIAGARA FALLS POWER CO.

equal right claim to be the home, *par excellence*, of the American electrochemical industry. Here, within a radius of two miles from the greatest source of water-power in the world, have grown up within the short space of eight years more than a dozen varied electrochemical industries; here, using power which costs less than half as much as power can be generated from coal (even if the coal were to be had for nothing), have grown up and developed into commercial successes processes which but a decade ago were merely ideas, visions in the fancy of a few electrochemical enthusiasts. The old adage, "knowledge is power," is being improved upon: the keynote of success at Niagara is "knowledge and power."

NOTE.—Owing to limitation of space, descriptions of the following plants are reserved for the following issue: Pittsburg Reduction Company, International Acheson Graphite Company, Carborundum Company and Acker Process Company.—ED.

brought to realization fancies which were undreamed of by the alchemists.

Combined with all the necessary supply of power, Niagara unites almost every other requirement for commercial development. The great lakes, with 3,600 miles of shore line, and navigable to the very docks at Niagara, give the cheapest sort of transportation to markets representing nearly half the population of North America, besides furnishing in many cases the cheapest sources of raw materials. Railways radiate therefrom in all directions; and, to add to it all, the falls with their great facilities are equally within two different countries, under different governments, one on a protection basis as regards imports, the other practically free trade, and the manufacturer can take his choice as to which policy is most favorable to his industry. He can even place one works in America,

to supply American trade, and one in Canada, to supply foreign trade. Truly, Niagara does present an almost embarrassing choice of advantages.

The canal to the edge of the gorge was built in 1861, and supplied power to several works and mills, who utilized from 20 to 50 feet of the possible 160-foot fall thus supplied. The canal was purchased by the Niagara Falls Hydraulic Power and Mfg. Co. in 1887, who increased the facilities for providing power and supplied it to some additional shops; but the great consumers of power—the electrochemical industries—were not yet far enough developed to enter the field, and the development of this great water-power had to wait upon the ripening of the electrochemical industry for its great *raison d'être*: the developing electrochemical industry gave incentive for and is practically the mainspring of the development of power at Niagara Falls. By the end of this year the Niagara Falls Power Co. will be developing 60,000 horse-power, 45,000 of which, or exactly three-quarters, will be used in electrochemical work.

The Hydraulic Power and Mfg. Co. have a canal, 36 feet wide and 8 feet deep, reaching from above the falls to the sides of the gorge below the town, on the American side, giving a head of 210 feet to the river below. Their principal power plant is located in the gorge at the water's edge and develops 30,000 horse-power, while 5,000 horse-power additional is generated by several smaller plants using only part of the available head, as is shown in the photograph by the various cataracts descending the cliff. This company have now the right to enlarge their canal to 100 feet in width by 14 feet in depth, which will give, it is estimated, a total of over 100,000 available horse-power. The selling price of this power varies from \$8 per horse-power per year, for those buying only the water right and putting in their own machinery, to \$20 or \$25 per horse-power per year for those buying the working current, adapted to their particular use.

The Niagara Falls Power Co., on the American side, above the falls, have wheel pits, 180 feet deep, connected with a tail-race tunnel, 21 feet in diameter by  $1\frac{1}{3}$  miles long, whose capacity to take away water is rated at 120,000 horse-power. The

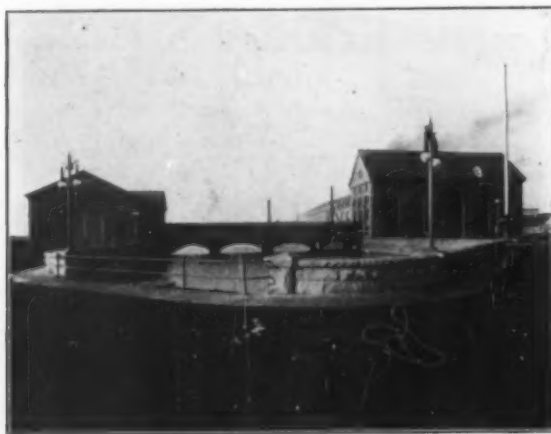


FIG. 2.—POWER HOUSE NO. 1 AND TRANSFORMER STATION, NIAGARA FALLS POWER CO.

per horse-power per year, transforming it at their own cost in present working station has ten 5,000 horse-power units in operation, and 5,000 horse-power additional to operate the local street railway system. The International Paper Co., located alongside this power house, have their own wheel pit and generating machinery, and use the tunnel for their tail race, thus employing 10,000 horse-power, for which is paid \$9 per year. Other companies using power from this plant receive the current at 2,250 volts, alternating, and pay for it \$18 to \$20

whatever way may be necessary for their special purposes. This company own 1,500 acres of ground, which is reserved for manufacturing purposes, and held at about \$1,000 per acre. The company are at present constructing a 55,000 horse-power plant, which is already under roof (as shown in photograph) and which will furnish the first 10,000 of their power in October, and it is an interesting feature that several of the works are now erecting additions, and that this first 10,000 horse-power was all contracted for several months in advance.



FIG. 3.—STATION NO. 2, NIAGARA FALLS POWER CO.

The Canadian-Niagara Falls Power Co. pay the Canadian Park Commission \$25,000 per year for the right to develop 250,000 horse-power on the Canadian side. Their power house, immediately to the left of the falls, is well under way, and will begin furnishing power in July, 1903. Other concessions have been made allowing 200,000 horse-power more to be developed on the Canadian side, but they are not yet being exploited.

#### THE CASTNER ELECTROLYTIC ALKALI CO.

This company were originally the Mathiessen Alkali Co., a branch of the Providence works of that company, and operated the Castner process first at Saltville, Va., in 1895. The present company may be considered the American representative of the Castner-Kellner Co. of England. The officers are B. F. Thurston, president; Max Mauran, superintendent. The patents operated under are those of H. Y. Castner (U. S. Patent 528,322, of 1894), and Max Mauran (U. S. Patents 674,927 and 674,930 to 674,934). The patent of Mr. Castner (who is now deceased) is the basic one, covering the principle of using a compound cell with movable mercury floor, partitions dipping into the mercury separating the cell into compartments, which are electrically independent of each other, and moving the mercury from one compartment to another by any mechanical means. The patents of Mauran are directed towards greater mechanical perfection of the details of the cells, but in no wise alter their principle of action.

The Castner cell, as installed by Mr. Castner, at Niagara, is a slate box, 4 feet wide, 4 feet long and 6 inches deep, the joints being made by rubber cement. Two partitions reaching within 1-16 of an inch of the bottom (under which are made grooves) divide the cell into three compartments, each 15 inches wide by 4 feet long, which are made independent of each other by mercury on the bottom and in the grooves, touching the partitions. The general plan of the process and its theory are so well known that it is unnecessary to rehearse them here, and we will confine our description to the actual apparatus used. The exterior compartments, through which brine flows, have numerous graphitized carbon anodes passing



FIG. 4.—STATION OF THE NIAGARA FALLS HYDRAULIC POWER AND MFG. CO.

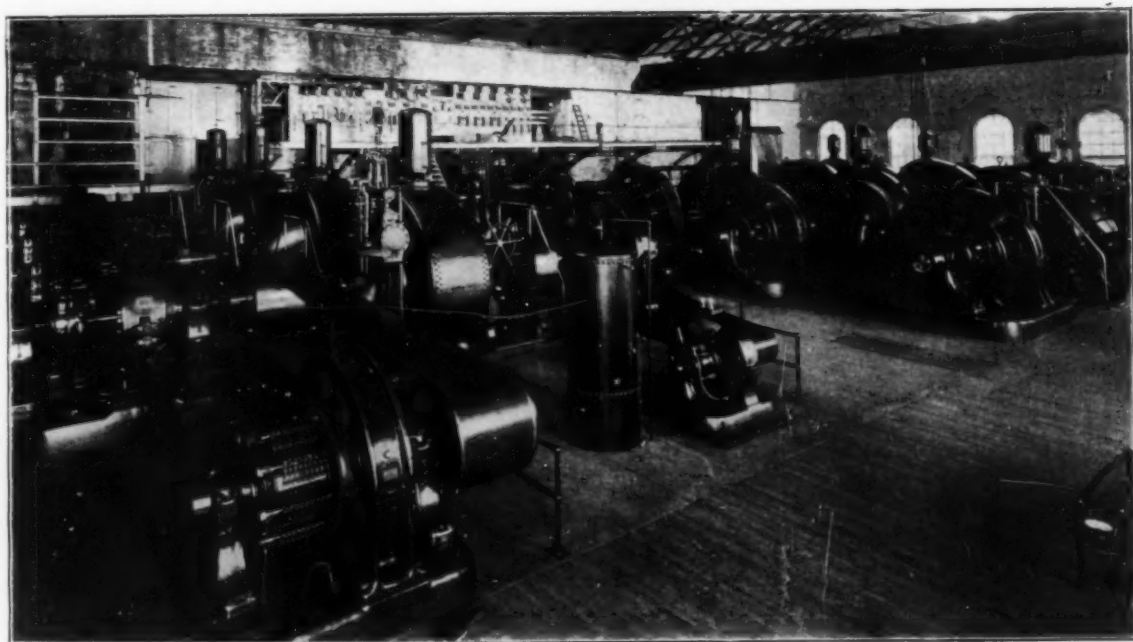


FIG. 5.—NIAGARA FALLS HYDRAULIC POWER AND MFG. CO'S STATION IN GORGE.



through the sides of the box with 1 inch of the surface of the mercury. There are 12 electrodes on each side, each 1 inch in diameter by 15 inches long. These compartments are provided with tight covers and exit pipes of rubber, connecting with lead pipes to carry off the chlorine. The central compartment has 20 sheets of iron hanging in it, which serve as cathodes for liberating hydrogen in the caustic soda solution. This compartment is supplied with pure water; it is covered loosely with a sheet-iron cover, and the liberated hydrogen escapes into the room. The cell is pivoted on two points on one side and rests on an eccentric on the other, which raises and lowers about  $\frac{1}{2}$  inch, once a minute. This suffices for the circulation of the mercury between the outer, or charging, and the inner, or discharging, compartments. The current passes through the brine in the outer compartments, liberating chlorine at the graphite anodes and charging the mercury with sodium; it then passes from the mercury in the central compartment to the iron cathodes, liberating hydrogen therein and setting free caustic soda in the solution. Only 90 per cent. of the charging current is allowed to pass through the discharging cell, because the efficiency of charging is not quite 100 per cent., while that of discharge is 100 per cent. or over, and the margin of 10 per cent. must be allowed in order not to oxidize the mercury by having a deficiency of sodium to discharge. This appears to be one of the severest difficulties of the process. The salt solution flows through continuously; the salt is from



FIG. 6.—CASTNER ELECTROLYTIC ALKALI CO.

the New York beds at Retsof, containing very little magnesium and but a small proportion of sulphates. The strong salt solution is not purified before going to the cells. On returning, it is strongly charged with chlorine, and has to be pumped by earthenware pumps. The sulphates accumulate to a certain point, when part of the solution is withdrawn from circulation, purified by use of barium chloride and returned to the circulating system. Water is run into the center compartments and allowed to remain until it has reached a certain concentration ( $54^{\circ}$  Twaddell), and then run off and replaced by fresh water. The caustic solution is evaporated to solid caustic in iron pans, 10 feet in diameter by 6 feet deep, and it will be readily seen that the stronger the solution from the cells the less evaporation is needed. The cells last indefinitely, the graphite anodes last one to two years, the iron cathodes are unchanged. The mercury is unattacked as long as sufficient of the charging current (averaging 10 per cent.) is shunted off from passing through the discharging cell. If the operator is anxious to "sail close to the wind" he may shunt off too little, and immediately blacken the mercury and cause the formation of mercury salts. Each cell contains in the neighborhood of 100 pounds of mercury, which costs more than the rest of the apparatus. (Slate apparatus is made in the Pennsylvania slate regions at prices hardly greater than if made of wood.)

The improvements on the original Castner cell by Mr.

Mauran have been as follows: a more efficient cathode has been made, the iron sheets being replaced by an iron grid (like an inlet grating), consisting of 20 strips the length of the cell, 1 inch deep and about  $\frac{1}{2}$  inch apart, united at the ends, where they rest on the cell walls, in order to make connections. The graphite rods passing through the sides of the box gave frequent trouble from leakage and offered considerable resistance. They have been replaced by blocks having much the shape of a rail section, which are cemented into the lid of the compartment, with their broad lower flanges offering large surface within  $\frac{1}{2}$  inch of the mercury, their upper parts projecting above the lid are connected by zigzag lead connections and paraffined heavily to preserve the contacts. The voltage necessary to run the cells has thus been decreased some 20 per cent.

Each cell receives 630 ampères and absorbs 4.3 volts. The voltage absolutely necessary for the decompositions is 2.3 volts, so that 53 per cent. of the energy of the current is actually used in the chemical transformation and 47 per cent. converted into heat. The watts thus converted into heat are, however, only 1,260, which would suffice to keep the cell only a few degrees above the normal temperature. The temperature of the cell may, in very hot weather, approach the danger line of  $40^{\circ}$  C., at which chlorate begins to be produced, but artificial cooling has not yet been found necessary with the current densities used. The current density at the mercury is 110 ampères per square foot, at the graphite anodes probably 150. The efficiency attained, calculating on the ampères of the charging current, is very close to 90 per cent.

The first plant at Niagara Falls, situated three-quarters of a mile above the upper power house, occupies a tract of ground 150 yards square. It contains storage rooms, power-converting plant, cell room, 200 feet square, evaporating house with ten evaporating pots and large bleaching-powder chambers. The power room contains ten stationary converters, each connected with a rotary converter. The 2,250-volt alternating current, supplying 700 ampères, is thus split up into currents of 70 ampères each, which are converted by the ten rotaries into ten currents of nearly 200 horse-power each, *i. e.*, 230 volts by 630 ampères. Each such current runs a double row of 54 cells in series. The theoretical quantity of materials treated per day of twenty-four hours, reckoning on an efficiency of 90 per cent., is as follows (in pounds):

	Per Cell	Per 510 Cells	Per H.-P.
Crude salt decomposed.....	65.25	35,200	17.6
Caustic soda produced.....	44.62	24,100	12.0
Bleaching powder produced (36 per cent. chlorine)....	111.54	60,200	30.1

The plant at Niagara was enlarged in 1901 by the construction on a neighboring site of a 4,000 horse-power plant, working on the same principles. The whole plant at Niagara represents, therefore, a capacity of 6,000 horse-power, using over 50 tons of salt daily, and producing therefrom 36 tons of caustic soda and 90 tons of bleaching powder. The 3,000 horse-power Acker process plant has about the same capacity as the 2,000 horse-power Castner plant. Between the Acker and Castner processes it is estimated that they produce nearly one-half of the caustic soda made in America.

Analyses of the caustic soda produced by the Castner process show it to contain 97 to 99 per cent. caustic, 1 to 2 per cent. of sodium carbonate (from contact with the air), 0.3 to 0.8 per cent. of sodium chloride, 0.03 to 0.10 per cent. of sodium sulphate and 0.05 to 0.10 per cent. of sodium silicate. The sulphate comes mostly from the water used to take up the caustic, the chloride from leakage from the brine chambers and the silicate from corrosion of the slate cells.

#### THE NIAGARA ELECTROCHEMICAL CO.

This company were formed to work the processes of H. Y. Castner for producing sodium, sodium peroxide and sodium cyanide. The manufacture of the first two is conducted at

Niagara, of the latter at Roessler and Hasslacher's works at Perth Amboy, N. J. The company were incorporated in 1895, and the principal stockholders are the Aluminum Co., Ltd., Oldbury, England, the Deutsche Gold and Silber Scheide Anstalt vormals Rössler, of Frankfurt, Germany, and Rössler and Hasslacher, 100 William street, New York. The English and German firms named also conduct similar manufactures under Castner's patents. The officers of the company are Franz Rössler, president; J. Hasslacher, secretary and general



FIG. 7.—NIAGARA ELECTROCHEMICAL CO.

manager, and Geo. F. Brindley, chemist and manager of the Niagara plant. The capital is \$100,000.

Castner's patent for producing metallic sodium is the U. S. Patent 452,030, of May 12, 1891; for producing sodium peroxide, U. S. Patent 494,757, of April 4, 1893; for producing cyanides, U. S. Patents 541,066, of June 18, 1895, 543,643, of July 30, 1895, and 577,837, of March 2, 1897. Only the first named is an electrochemical process.

The process consists, according to its claims, in electrolyzing caustic alkali constantly maintained at not more than 20 degrees above its melting point; and, also, in using a gauze or screen between the electrodes and a superposed dome for collecting the metal. The temperature must be kept low in order to prevent the re-solution of metal by the bath and re-combination, which take place actively at higher temperatures. Caustic soda melts at 308° C., if pure, but down to 300° if it contains slight impurities. It is electrolyzed preferably within 10° of its melting point, but never above 325°. Within five degrees of its melting point, almost the theoretical quantity of sodium is obtained, at ten degrees above, about 90 per cent., and this is the best attainable in commercial practice, above this the yield decreases very rapidly, and at 20 degrees above its melting point re-combination is as active as decomposition and the bath yields no metal, but lies "dead."

On commencing to pass the current through melted caustic soda, any water present is at first decomposed, evolving hydrogen and oxygen only until every trace of water has gone. After that sodium and hydrogen together appear at the cathode, and oxygen at the anode. These must be kept rigorously separated or re-oxidation of the sodium will occur, and the hydrogen will be oxidized, with an explosion. Castner achieves this by hanging a gauze or screen all around the cathode, the meshes of which are large enough to allow the electrolyte to circulate through it freely, but small enough to prevent either globules of sodium or bubbles of hydrogen or oxygen gas from passing through. The sodium collects on top of the electrolyte, and is thence run off or ladled out.

Castner's apparatus consists of a conical iron pot, 18 inches in diameter by 2 feet deep, set in brick work. The carbon cathode comes up through the bottom, through a sleeve-like tubular prolongation, 12 inches long, in which the melted caustic sets and forms a tight joint. The top of the rod has an enlargement 4 inches in diameter, standing about in the mid-

dle of the pot; this is the active cathode. Surrounding this is a 6-inch circular anode of iron or, better, nickel, and between these is a 5-inch circular cylinder of nickel mesh, suspended from a solid 5-inch cylinder, which reaches above the surface of the caustic and is covered over by an iron lid having small holes for escaping hydrogen. Such a pot holds 250 pounds of melted caustic, and a current of 1,200 ampères is passed through it, dropping 5 volts to a pot. The current density at the cathodes is, therefore, about 2,000 ampères per square foot and at the anodes 1,500. Four rows of 30 such pots are in operation at this plant, using 1,000 horse-power and producing daily, at an assumed efficiency of 90 per cent., 52 pounds of sodium per pot, or 6,250 pounds for the whole plant. This is a little less than 4 horse-power per hour per pound of sodium, whose cost would be only 1/2 cent. Since caustic soda costs only 2 cents per pound or 4 cents per pound of sodium produced, and the labor should not amount to over 3 cents per pound, while deterioration of apparatus, remelting and packing may be put at 2 1/2 cents more, the whole cost of sodium by this process is probably not over 10 cents per pound. Its market price is 35 cents per pound, but the demand for the metal is limited. The greater part of the product is converted into sodium peroxide, by passing air over the sodium at a certain temperature in iron tubes. The product contains 95 to 97 per cent. of peroxide and 3 to 5 per cent. of carbonate and moisture, and commands 35 cents per pound in ton lots.

The *bête noire* of the sodium business has always been the limited demand and restricted uses for the metal. That this company is successfully solving the problem is evidenced by the doubling of the size of the works last year. The present plant covers two acres and employs 60 men. May they still increase!

#### THE NORTON EMERY WHEEL CO.

This is an old-established firm, located at Worcester, Mass., which have purchased from the Ampère Electrochemical Co. the patent of Chas. B. Jacobs for fusing bauxite in an electric furnace and thereby producing a pure artificial corundum. This process consists in fusing the natural bauxite and allowing it to cool slowly, when it acquires the hardness of



FIG. 8.—NORTON EMERY WHEEL CO.

corundum and the toughness of emery, and is suitable for wheels, stones, cloth, paper and all the various uses of an abrasive.

The process was originally operated at the plant of the Ampère Electrochemical Co., in a revolving furnace of the Horrey carbide type. During the process of fusion the carbon electrodes exert a slight reducing action, as is shown by the occasional finding of small buttons of iron, silicon and titanium scattered through the product.

The works of the Norton Emery Wheel Co. are situated about one mile above the upper power house, and is a brick building, two stories in height, covering 60 by 90 feet, erected in 1901. The gentlemen in charge are A. C. Higgins, general manager, and S. F. Hall, superintendent. The building contains office, laboratory, calcining furnace and melting furnaces. The bauxite is first taken to the upper floor, where it is charged into the upper end of a calcining furnace fired by coal. Here the bauxite is completely calcined, and is taken out at the lower floor level. It is then hoisted to the upper floor, where the melting furnaces are operated. The power used is 500 horse-power. The method of operation is similar to that of the experimental work already described, and is carried on in furnaces into which dip the two carbon terminals. These terminals dip into the melted bath, and fresh bauxite is added as soon as the contents are melted. The method of regulating the distance of the carbons in the bath and of protecting the furnace lining are matters which have been very satisfactorily solved.

After a run the carbons are taken out and the mass allowed to cool three or four hours in the furnace, after which the block is removed from the furnace and left on the floor to cool. Then it is broken up into pieces of convenient size, roughly sorted and shipped to the main works at Worcester, Mass. The best product is horny, or flinty in appearance, while some beautiful small crystals of pure alumina are at times found, colored blue, like sapphire, or pink, like ruby. They are, in fact, the artificial gems, but too small to possess value as such.

#### THE UNITED BARIUM CO.

This company were formed to acquire and work the processes of working barium sulphate into other barium salts, which was developed to commercial working by the Ampère



FIG. 9.—UNITED BARIUM CO.

Electrochemical Co. The officers of the company are G. S. Etna, president; W. H. Miller, vice-president; J. G. Petrekin, treasurer, and T. L. Welles, works superintendent.

The process acquired is that patented by C. S. Bradley and C. B. Jacobs (U. S. Patent 624,041, of 1899; German Patent 111,667, of December 16, 1898). The principle employed is that of melting in an electric furnace a mixture of barium sulphate with a small quantity of carbon, usually only one-nineteenth of its weight. If sufficient carbon is present, all the sulphate is reduced in the electric furnace to sulphide, according to the reaction

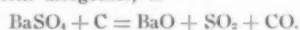


requiring one part of carbon to five parts of sulphate, and reproducing the ordinary furnace reaction for making the sulphide. If barium sulphate and barium sulphide are fused

together, at the heat of an electric furnace, however, they will react according to the formula



but this reaction cannot be produced at ordinary furnace heats. If, therefore, just one-fourth as much carbon is used as is necessary to reduce the sulphate to sulphide, the one-fourth of sulphate reduced to sulphide reacts upon the unchanged three-fourths and the oxide is obtained. The sum total of the two reactions, written altogether, is



The reaction is not perfect, however, and in general only about two-thirds of the sulphate is converted into oxide, nearly one-third remains as sulphide and only a very small fraction remains unchanged, some 1 to 3 per cent.

There are two furnaces now in operation working this process. They are of the direct-heating arc type, the carbons being adjustable and playing an arc onto the fused material. The body of the furnace is lined with carbon blocks, and the contents are tapped out from time to time as the furnace gets full of melted material. The carbons are raised and lowered by means of small electric motors, controlled by the workmen, and pass through a square opening in a grid of wrought-iron pipes, cooled by a stream of water, and covered with a non-conducting cover. The workmen can thus feed in material while standing close to the furnace, but the mixture of barium sulphate and carbon must be fed in slowly, because the gases evolved by the reaction are large in volume and would cause violent boiling if melted too quickly. Attempts are being made to recover the sulphur dioxide evolved, so as to convert it into sulphuric acid. Each ton of sulphate furnished gives off enough of this gas to make one-half a ton of 50 per cent. sulphuric acid.

The plant is being enlarged so as to manufacture 60 tons of barium hydrate,  $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$ , per day. The present output is stated to be 12 tons daily. There are three 400 horse-power furnaces, each taking 2,500 ampères at 120 volts, and at this output, allowing that only 60 per cent. of the sulphate is reduced to oxide, the efficiency of the furnaces would count up 74 per cent. absorbed in heating up and melting the mixture and in the chemical reactions, while 26 per cent. would be lost by radiation.

The furnace product is tapped out, running into cakes about 3 feet by 4 feet and 3 inches thick. This is broken up and digested with hot water, leaving very little insoluble sulphate, but the material is about 60 per cent. barium oxide and 40 per cent. barium sulphide, which go into solution as 60 parts hydrated oxide, 20 parts sulphide and 20 parts sulphhydrate. On cooling the filtrate, the hydrate,  $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$  crystallizes out and is separated in centrifugals. When dried and packed it sells at 3 cents per pound. The mother liquors are treated to recover their barium as carbonate and also to recover the sulphur in them, by methods which are not yet quite worked out and which the company are not ready to publish.

The raw material, barite from Missouri, costs \$2.50 per ton where found, but the railway freight raises its cost to some \$6 per ton at Niagara. It is about 90 per cent. pure. To obtain cheaper material, the company have acquired a remarkable deposit of barite on the north shore of Lake Superior near Silver Island. The cliff here is 50 feet high, and a vein of pure white barite, 77 feet wide, with perpendicular strike, is exposed for the whole height of the cliff and is visible 30 feet down in the water, while it has been traced on shore a distance of 600 feet back from the water. At a moderate calculation, 250,000 tons of barite are in sight, which can be shipped from the spot to the company's wharf at Niagara more cheaply than Lake Superior iron ore can be carried to Pittsburg.

The uses of the company's products are various. Barium hydrate finds application in the paint trade, for making white paints; in the sugar trade, for recovering sugar (as insoluble



barium saccharate) from waste dilute solutions, and for softening boiler waters. The mother liquors from the crystallization of hydrate, containing barium sulphide and sulphhydrate, have been found useful in removing hair from hides, a solution diluted to 2½ per cent. removing all the hair from a hide in 3½ hours' immersion, without any injury to the leather. The same solution is very suitable for making the white paint called "lithophone," which is made by running a solution of zinc sulphate into barium sulphide solution, thus producing the precipitated pigment, a mixture of barium sulphate and zinc sulphide. The mother liquors can also be converted into barium carbonate, which has found application in the cyanide industry and also in the manufacture of bricks; for mixed in small proportion with the clay it is said to prevent red bricks from turning white and white bricks from turning green.

Such are some of the many ramifications of the electrical-barium process, and in the further prosecution of that most interesting business we wish our Niagara friends *bon voyage*.

#### THE OLDBURY CHEMICAL CO.

This company are virtually the American branch of Albright and Wilson, manufacturing chemists of Oldbury, England.



FIG. 9.—OLDBURY CHEMICAL CO.

Their New York agents are J. L. and D. S. Riker, Cedar street, New York. Hugh A. Irvine is the manager. The plant is near that of the Roberts Chemical Co., and uses 1,000 horse-power in the production of yellow phosphorus and potassium chlorate. The works cover 3½ acres and employ 60 men. The output of chlorate is given as 30,000 pounds per month and that of phosphorus an equal amount. If these figures are reliable, the current efficiency of the works is exceedingly high, compared with others in the same lines.

The Readman-Parker process of producing phosphorus is used, in which natural phosphate is intimately mixed with carbon and sand, and placed in a retort-like furnace heated inside by the electric current passing between carbon poles, it being a type of resistance furnace. The phosphorus distills off and is condensed under water, the calcium silicate slag is tapped out intermittently. About 80 to 90 per cent. of the phosphorus in the raw material is recovered and only 170 pounds a day are obtained from one furnace. (*Mineral Industry*, Vol. VII.) It would take, therefore, six furnaces to make the output quoted, which would be of 50 horse-power each.

Mr. Irvine has patented an improvement on the method of heating the charge in his furnaces (U. S. Patent 681,367) consisting essentially in using a granular core of carbon as a

heating agent, surrounding it with the charge material and passing the current. As soon as the charge melts, forming a body of slag, the carbon floats up and the current thenceforth passes through the slag, which then serves as the vehicle for melting fresh portions of charge.

#### THE AMPERE ELECTROCHEMICAL CO.

This company are a decided innovation, in that they are not an operating company, but an experimenting company, formed to discover and develop new electrochemical processes and bring them to the point of commercial application. The founders of this company were Prof. F. B. Crocker, president; C. A. Doremus, vice-president; S. S. Wheeler, treasurer; C. S. Bradley, inventor, and they have associated with them A. H. Buch, H. E. Knight, D. R. Lovejoy, Chas. B. Jacobs and N. Thurlow as chemists. The company originally located at Ampère, N. J., but in 1898 established themselves at Niagara. The processes so far developed by this company are as follows: the method of fusing bauxite to produce artificial corundum, sold to and now operated by the Norton Emery Wheel Co.; the method of treating barite (natural barium sulphate) to produce barium hydrate, sold to and now operated by the United Barium Co.;

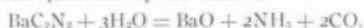
the method of producing nitric acid from nitrogen and oxygen, operated by the Atmospheric Products Co.; a method of producing camphor from turpentine, discovered by Mr. Thurlow, and being now installed at Port Chester, N. Y., on a scale sufficient to produce one ton of camphor per day. Besides these, the company are working on the production of cyanides by the fixation of atmospheric nitrogen, the production of artificial rubber, the production of new fertilizers and the manufacture of several new silicides. We will consider by themselves the processes already being operated at Niagara by other companies, and will under this heading describe only those processes of the Ampère Electrochemical Co. which are in process of development.

**Manufacture of Cyanides.**—By heating a mixture of barium oxide or carbonate with carbon in the electric furnace, barium carbide quite similar to calcium carbide is obtained. Its formula is  $BaC_2$ , and it is very probable that it is an unsaturated compound of the same type as acetylene,  $H_2C_2$ , and, therefore, containing two carbon atoms, which temporarily neutralize each other's affinities. Such compounds easily form additional compounds, and it has been found that by heating the barium carbide and passing nitrogen gas over it, the latter joins onto the carbon and forms barium cyanide,  $BaC_2N_2$ . Air will not

do for this reaction, of course, because its oxygen would oxidize both the barium and carbon, but the oxygen must either be first removed or else rendered inert, which may be done by converting it into carbonic oxide—a process amounting to using producer gas. With this gas as the reagent, the cyanide can be formed with but little oxidation. The mass being leached with water, the cyanide goes into solution, and may then be treated with a soda salt, such as the carbonate, to precipitate barium carbonate and leave in solution the sodium cyanide. Another alternative is to treat the barium cyanide in a closed vessel with dilute acetic acid, under reduced pressure, and passing the hydrocyanic acid gas into caustic soda solution, to produce the cyanide, leaving barium acetate behind. The mere evaporation and distillation of the latter in a closed vessel leaves behind barium carbonate and distills off very pure acetone, much purer than is commercially obtained from calcium acetate. The barium carbonate is then used over.

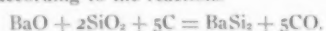
The company are now working industriously on the commercial installment of the process above outlined, which, experimentally, has promised very good results.

*Manufacture of Ammonia.*—There is a possibility that by passing steam over the barium cyanide, ammonia may be made in commercial quantities by the reaction

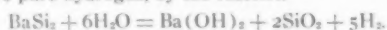


The writer does not know how far this possibility has proven successful.

*Manufacture of Silicides.*—In July, 1899, this company succeeded in producing the silicides  $\text{CaSi}_2$ ,  $\text{BaSi}_2$  and  $\text{SrSi}_2$ , which are analogous to the carbides  $\text{CaC}_2$ , etc. (U. S. Patents to Jacobs, 656,353 and 656,354, of 1900). They are formed in the electric furnace by heating to a comparatively high temperature (higher than that needed for carbides) a mixture of carbonate, oxide, sulphate or phosphate of the metal concerned with silica and sufficient carbon to effect the reduction; as, for instance, according to the reactions



These silicides are crystalline, bluish-white, and in contact with water give pure hydrogen, by the reaction



One pound of calcium silicide will thus generate, in a common acetylene generator, 18.5 cubic feet of pure hydrogen; or it would require 54 pounds per 1,000 cubic feet of hydrogen. These qualities suggest a field for generating hydrogen in the laboratory or for ballooning purposes. It is also stated that barium silicide has the property, if put into melted iron or steel, of combining with the sulphur and phosphorus present therein, removing them in the slag as barium sulphide or phosphide, and experiments made on steel at Newark are said to have succeeded in removing the injurious sulphur and phosphorus completely. They are also good reducing agents, working in either acid or neutral solutions.

*Manufacture of Camphor and Rubber.*—These are made from turpentine by a purely chemical process, not electric, so their consideration is here omitted.

These are but a part of the ideas which this company are working up into commercial processes, and if one considers the combination of forces which this company command—some veteran inventors, some college professors, some college-trained chemists and electricians, some business men, and all enthusiastic, persevering workers—it is safe to predict that many more valuable processes will be brought to light as their reward.

#### THE ELECTRICAL LEAD REDUCTION CO.

This company were organized to work the electrolytic method of reducing lead sulphide or native galena, patented by Pedro G. Salom, of Philadelphia. The officers are Pedro G. Salom, president; Henry G. Morris, vice-president; F. H.

Deacon, secretary and treasurer. The chemist is A. L. Weightman; superintendent, S. Weil. The company have a paid-in capital of \$200,000, they issue preferred stock \$2,000,000 and common stock \$10,000,000.

The process has been described by Mr. Salom in the *Transactions of the American Electrochemical Society*, Vol. I, 1902. The idea of the process is, briefly, to use crushed and pure galena as cathode in a dilute solution of sulphuric acid, where it is reduced, the sulphur going off as hydrogen sulphide. Two Westinghouse 300 horse-power motors are run on the



FIG. 11.—ELECTRICAL LEAD REDUCTION CO.

alternating current of 2,250 volts, and each is directly connected with a Westinghouse direct-current 250 horse-power generator. The reduction pans are of antimonial lead, 15 inches across at the bottom and 18 inches at the top, round and 6 inches deep. The galena is spread on the bottom in a layer of fine material, 1 inch thick, dilute sulphuric acid is put in, the sides of the pan are protected by a rubber lining, and the bottom of a similar pan placed on top becomes the anode. The pans are thus stacked 11 high, the bottom of each pan serving as anode to the pan beneath it. Thirty-three pounds

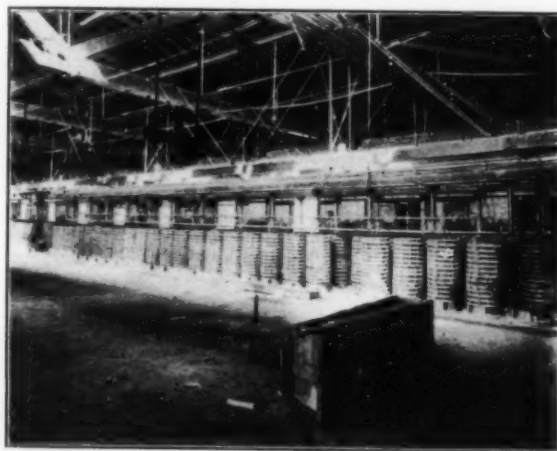


FIG. 12.—CELL ROOM, ELECTRICAL LEAD REDUCTION CO.

of galena is thus subjected to a current of 33 ampères, requiring 2.9 volts, and is treated 5 days. The ore is reduced *in situ* to spongy metallic lead, swelling up to 3 or 4 inches thickness. The gases escaping are a mixture of hydrogen and hydrogen sulphide, the proportion of the latter in the gas gradually increasing from zero to a maximum, in one day, and then gradually declining. The stacks are grouped in fours, run in parallel, so that the current of 125 volts runs through four stacks in series (equals 44 pans) and runs through several of such groups in parallel.

The cell room is 140 by 182 feet, and has room for 10 rows of 22 stacks each, whose capacity would be 10 tons of lead per day. Only two of these rows have been installed so far, but the rest of the room is being filled with an improved type of cell, which works much more quickly and satisfactory, and which will be described by Mr. Salom before the Niagara meeting of the American Electrochemical Society, on September 15th, next. This apparatus is particularly designed to obviate the incompleteness of reduction, which has given considerable trouble.

The gases escaping are conducted in lead pipes to a combustion chamber, where they are burned, either completely, so as to recover sulphuric acid, or incompletely, so as to recover sulphur. The spongy lead is first washed on a sloping table, with a hose, and using a hoe in order to remove light impurities, such as quartz, zinc sulphide, etc. It is then dried in a revolving cylinder of iron over a furnace. It is then ready for use in storage batteries. Most of it is converted into litharge, by burning it on the hearth of a reverberating furnace. In this way an hour's treatment converts it completely into litharge, which is cooled, washed, to remove any unconverted lead, and dried. The product is clean and pure, and finds a ready market with glass and rubber makers. Mr. Salom has also patented processes for the conversion of this sponge into other lead salts, such as carbonate, chromate, dioxide and for pressing it into a compact storage-battery plate.

The process is based on sound electrochemical principles and also sound economic principles. The electrochemical equivalent of lead is so high that very little electric power is needed to reduce it; theoretically, for instance, a current which would liberate 1 part of aluminum would set free  $11\frac{1}{2}$  parts of lead. The process furnishes the lead in a condition highly suitable for solution or corrosion or conversion into other lead salts, while it is in exactly the condition required for storage-battery work. If Mr. Salom can secure the complete reduction of all galena, his process will have an economic future which his present Niagara plant will not be able to take care of.

#### THE ROBERTS CHEMICAL CO.

The plant of this company is nearly two miles from the upper power house. It is a one-story frame building, 60 by 200 feet, and utilizes 500 horse-power in the manufacture of caustic potash and hydrochloric acid from potassium chloride. The officials of the company are W. S. Block, president; H. G.



FIG. 13.—THE ROBERTS CHEMICAL CO.

Wilson, treasurer; S. D. Benoliel, general manager; Ross Phillips, chemist. The company own and operate the patents of I. L. Roberts (U. S. Patents 673,452 and 673,453) for electrolytic apparatus and connections. No further details of the working of this company are available.

#### A. J. ROSSI.

This veteran pioneer in the field of ferro-titanium is still reducing titanium ores on a semi-commercial scale at Niagara

Falls. His 200 horse-power furnace is situated in a stone building between the plants of the Electrical Lead Reduction Co. and the Acheson Graphite Co. Here he is reducing ilmenite, titanite ore containing 65 per cent. of ferric oxide and 35 per cent. of titanite acid, in the electric furnace, producing at will a high ferro-titanium, or, by using lime as flux, an almost pure cast iron. He makes two grades of ferro-titanium, one with 4 per cent. of titanium, for use in cast-iron foundry work, and the other with 10 per cent. of titanium, for use in steel. The 3 to 5 per cent. alloy melts easily at the heat of a foundry cupola, or of melted cast iron, and is particularly valuable for making a high quality of car-wheel castings. The 10 per cent. alloy melts at the heat of a steel-melting furnace and is claimed by Mr. Rossi to impart wonderful virtues to steel.

#### THE NATIONAL ELECTROLYTIC CO.

The plant of this company is below the falls, and they receive direct current of 2,000 horse-power from the power



FIG. 14.—THE NATIONAL ELECTROLYTIC CO.

house about 500 feet away. The plant at Niagara manufactures potassium chlorate under the patents of W. T. Gibbs, viz.: U. S. Patent 665,426 and 665,427, of January 8, 1901, for the manufacture of chlorates, and U. S. Patent 655,679, of same date, for an electrolytic apparatus.

The process used consists in principle in the electrolysis of a solution of potassium chloride, using a copper or iron cathode and a platinum anode, the electrodes being but a very small distance apart, using a high current density, a temperature above  $40^{\circ}$  C. and no porous partition. Under these circumstances, chlorate is abundantly formed, passes out of the apparatus before the solution contains a high percentage of it and is crystallized out by cooling the solution. The efficiency of the operation is a datum which the company do not desire to publish, their first experiments were said to have yielded 55 to 60 per cent. of the theoretical amount of chlorate, and their present practice is somewhere nearer to 70 per cent. efficiency.

The apparatus employed consists of rectangular wooden frames, 18 by 26 inches inside, alternating with lead plates, placed together in a frame like a filter press, with rubber gaskets between. One side of the  $\frac{1}{4}$ -inch gaskets is against the iron or lead plate, the other against the copper or iron cathodes. The wooden frames being covered with lead, furnish electrical connection from cathodes to anodes. The anodes are platinum foil supported on the lead or iron plates. They are unattacked. The cathodes were originally of wire gauze, covered with oxide of copper, it being the idea that the hydrogen there set free would reduce these oxides and thus de-polarize the electrode and diminish the potential necessary for running the cell. Such cathodes were not satisfactory and have been replaced by bare copper. They are in the form of rods, forming a grid with transverse strengtheners, and with insulating rods to keep them from touching the anodes, from

which they are only 1-64 of an inch distant. The distance of some 2 inches between the pairs of electrodes allows a considerable volume of solution to present itself for electrolysis, and, being well circulated, obviates the difficulties which would otherwise arise from having the electrodes within 1-64 of an inch of each other. The open, grid-like formation of the cathodes renders this scheme effective. Solution of potassium chloride runs into each cell continuously, at the rate of about one cubic foot each thirty minutes, at a temperature of 20° C., and its flow is so regulated that the temperature of the cell remains above 40° C. and averages 70° C. The chlorate reaction takes place properly as the temperature keeps above 50°, but is interfered with greatly by impurities in the solution, such as insoluble or colloidal precipitates.

Any number of such cells may be put into one frame, in

The manufacture of potassium chlorate is one of the oldest of electrochemical manufactures, but an inspection of the plant of this company certainly justifies the statement that their arrangement of plant and manner of working are not excelled, and probably not equaled by any other works in this line of business.

#### THE ATMOSPHERIC PRODUCTS CO.

This company are an offshoot from the Ampère Electrochemical Co. They were incorporated early in 1902, with a capital stock of \$1,000,000. Chas. S. Bradley is president and D. Ross Lovejoy, electrician. The process was evolved by Bradley and Lovejoy, and has been worked out in detail mostly by Mr. Lovejoy. The U. S. Patent is allowed, but not yet issued; the English Patent is 8,230, of June 8, 1901. The patent is for

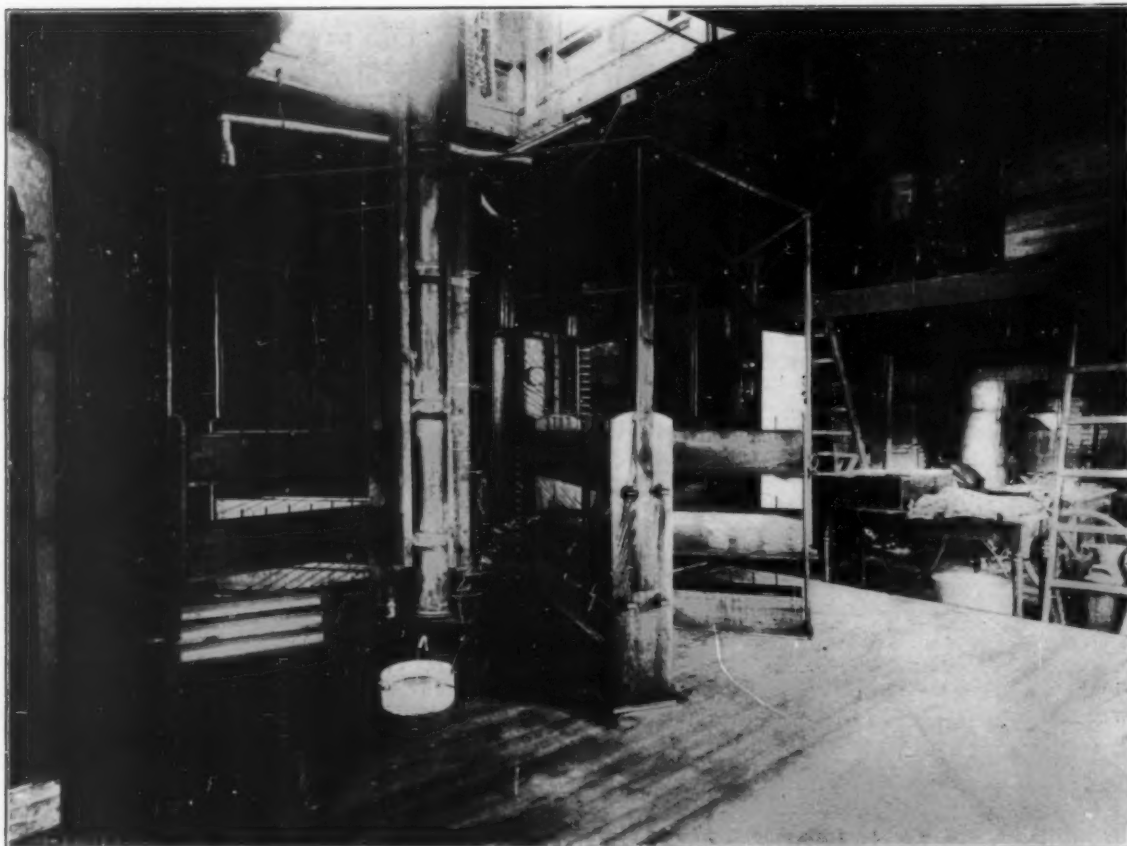


FIG. 15.—NITRIFICATION CHAMBER AND COLLECTION TOWER. THE ATMOSPHERIC PRODUCTS CO.

form like a filter press, with rubber gaskets between and screwed up water tight. The current is then passed through them in series, with a current of 1,650 ampères, giving a current density at the anode of 500 ampères per square foot. Since the conversion of chloride into chlorate absorbs 1.4 volts in the decomposition, about one-third of the energy of the current is used up in chemical work, while two-thirds are converted into heat, sufficient, theoretically, to raise the temperature of the cell 5° C. per minute, if it were not kept cool by the circulation of the electrolyte. The issuing stream is from 50° to 70° C., and foamy from evolving hydrogen. A cell of this kind is said by Kershaw (article in the *London Electrician*) to have been patented to Gibbs and Franchot in 1893, to have been experimented with in 1895 and to have given, on a two months' trial, 4,386 pounds of chlorate per horse-power per day, which is an efficiency of 67 per cent.

a manner of producing nitrogen compounds from atmospheric nitrogen, and points out that whereas the silent electric discharge and the spark or disruptive discharge can cause nitrogen and oxygen gases to combine, they have very little capacity in this respect, which is also the case with the electric arc, as ordinarily used. To obtain efficiency, it is necessary to use an arc, divided up into such small, thin, flat subdivisions as to present a large surface for a small amount of energy; the thinner the arc is the greater is its efficiency up to the point where it breaks. It is necessary, therefore, to greatly subdivide the current, to arrange the arc circuits in parallel and to provide against short circuiting.

The experimental apparatus of this company is installed at the works of the Ampère Electrochemical Co. They use a 45 kilowatt generator, ordinarily delivering 0.75 ampères direct current at a potential of 8,000 volts, but capable of giving sev-



eral ampères at as much as 15,000 volts. This remarkable generator was built by the Wayne Electric Co. The current supplies 138 arc contacts, each of which is made and broken 50 times per second, giving to each arc some 0.005 ampère. The arcs are all sprung successively, 6,900 per second in the apparatus, each arc lasting about 1-20,000 of a second, and thus giving practically a steady load to the machine. As each tends, the moments it is formed, to increase suddenly in



FIG. 16.—SWITCHBOARD OF ELECTRICAL MEASURING INSTRUMENTS.  
THE ATMOSPHERIC PRODUCTS CO.

volume, the short circuiting which this would produce is retarded by placing inductance coils or resistances in series with the arcs. These are so calculated that during about 1-40,000 of a second they impede the flow of current, therefore preventing too high an ampèreage flowing, and during the succeeding 1-40,000 second, while the arc is being drawn out and is about to break, it sends an impulse which increases the flow and so prolongs the arc. Using 8,000 volts, with an

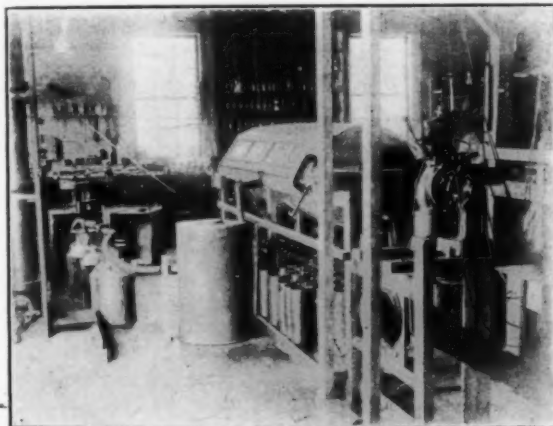


FIG. 17.—EARLY EXPERIMENTAL APPARATUS.  
THE ATMOSPHERIC PRODUCTS CO.

average current of 1-200 of an ampère to an arc, the arcs are drawn out 4 to 6 inches. By keeping a constant flow of air into the apparatus, the per cent. of combined products in the issuing air is only 2 to 3 per cent., and much less by dissociation is thus avoided by keeping down the concentration of nitric oxides. The patent claims are for "exposure of a mixture of nitrogen and oxygen to the action of an electric arc, and renewing the mixture so as to prevent dissociation."

The apparatus used at Niagara is 5 feet high by 4 feet in diameter, circular, of iron and has in the sides six rows of inlet wires, 23 in each row, the wires entering being well insulated by a porcelain sleeve and terminating in a short

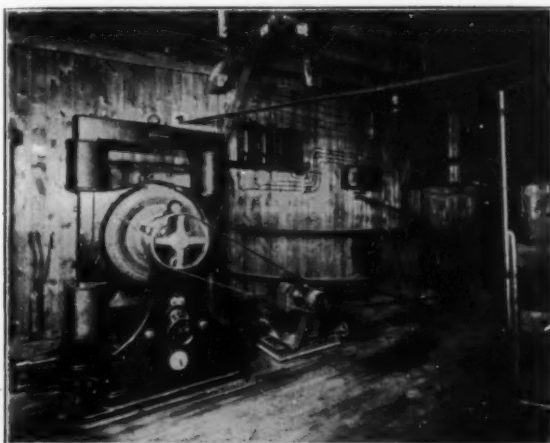


FIG. 18.—MOTOR AND 10,000-VOLT DYNAMO, WITH EXCITER.  
THE ATMOSPHERIC PRODUCTS CO.

platinum wire,  $\frac{1}{2}$  inch long, turned downwards. In the center of the apparatus is a vertical shaft, containing a series of 23 radial arms, each corresponding to the 23 rows of points,

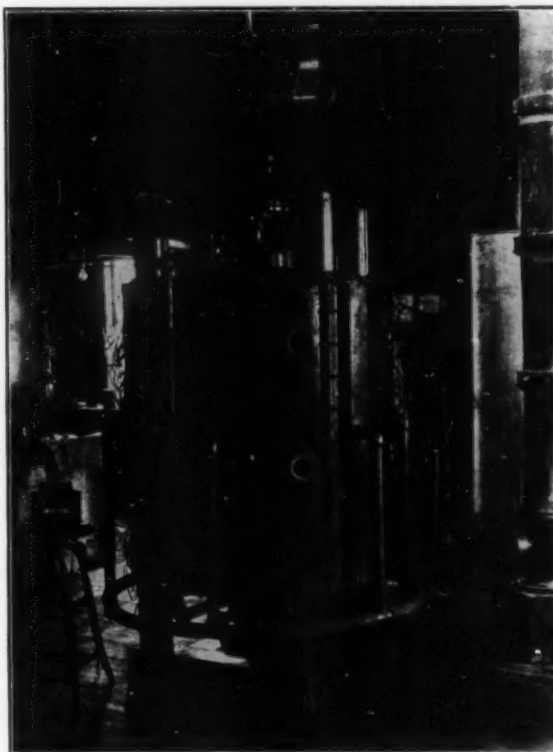


FIG. 19.—CHAMBER WITH INDUCTANCE COILS DISCONNECTED.  
THE ATMOSPHERIC PRODUCTS CO.

exterior wires, and there being six radial arms in each plane. The radial arms are tipped with short platinum wires, which come within 1-25 of an inch (1 millimeter) of the platinum wires of the opposite poles. As the two points approach, a

spark jumps about  $\frac{1}{8}$  inch to meet the approaching point, and then the arc is drawn out 4 to 6 inches by the retreating point. Each arc has in series a resistance coil, 5 inches in diameter by 12 inches long, immersed in oil, and containing several thousand turns of fine wire. The central shaft is run at 500 revolutions per minute, and takes a little over 1 horse-power; run at 1,000 revolutions per minute, it takes some 5 horse-power. The output is represented by one pound of theoretical  $\text{HNO}_3$  per 7 horse-power per hour of electric current used.

Air can be used in the apparatus, first carefully dried to

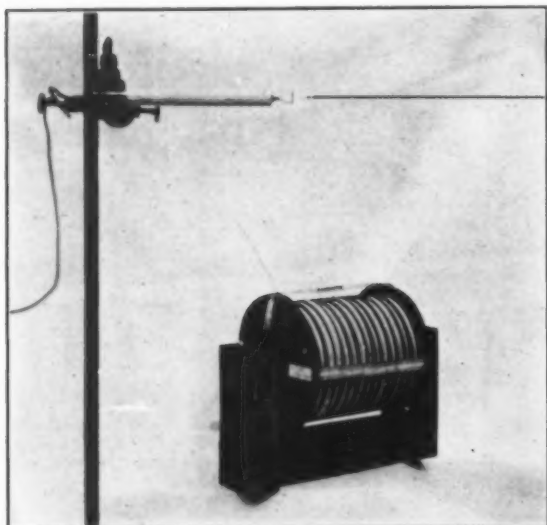


FIG. 20.—INDUCTANCE COIL, AND A PAIR OF ELECTRODES. THE ATMOSPHERIC PRODUCTS CO.

avoid formation of acid in the apparatus and consequent corrosion of the metallic parts. The inside of the apparatus is protected by a coating of asphalt varnish and glass peep-holes are provided, permitting inspection of the interior. A mixture containing equal parts of oxygen and nitrogen works better than air, giving a higher return for the current used. This is quite natural, since air contains 1 volume of oxygen to about 4 of nitrogen, whereas the gases formed contain 1 volume of oxygen to  $1\frac{1}{2}$  or 2 volumes of nitrogen. Air can be enriched to 50 per cent. oxygen in Linde machines at the rate of 1 cubic meter per horse-power per hour. The efficiency obtained increases as the ampère per arc decreases, until the arc degenerates into a spark. The gases are renewed at the rate of 3 to 4 cubic feet per minute, in order that the issuing gases may not contain over 3 per cent. of nitrogen oxides. The temperature in the generator is thus kept at about  $80^\circ\text{C}$ . The issuing gases pass into an iron reservoir, 2 feet in diameter by 10 feet high, where they have a chance to still further combine and thence pass into a scrubbing tower to condense the gases produced. This is an earthenware pipe, 9 inches in diameter by 25 feet high, filled with coke, over which trickles water if acid is desired, or a solution of caustic alkali, if alkaline nitrate is wished. The latter is the more convenient for experimental work, as the amount of time necessary to neutralize a given quantity of alkali gives an accurate measure of the output of the apparatus. In commercial practice, water towers will be used to obtain nitric acid, for which there is a market for 100,000 tons a year in the United States, while Lunge's scrubber, supplied with milk of lime, will be used to produce calcium nitrate, for fertilizing purposes. This is a cheaper way of getting the nitrogen onto the fields than using soda, because lime costs only \$1.50 per ton and is needed also by many soils.

The process has worked so successfully and promisingly on this experimental scale, that the company will engage in the commercial manufacture as soon as the power company have current to supply. It is proposed to begin with 2,000 horse-power. Since the space required for apparatus will be large, a large tract of ground, permitting future extensions, is to be acquired. Since the cost of apparatus will also be heavy, the company are already building a machine shop, 50 by 150 feet, two stories high, near to the Pittsburg Reduction Co's plant, where they will build their own apparatus. To supply all the nitric acid used in the United States would require a plant of some 150,000 horse-power, covering many acres of floor space, but such is one of the possible future developments of this process.

#### THE UNION CARBIDE CO.

Calcium carbide was first made industrially by Mr. Willson, at the Willson Aluminum Works, at Spray, N. C., in 1891. Since then its manufacture has become one of the largest of the electrochemical industries, it being estimated that the total capacity of calcium carbide works in the world is 250,000 horse-power, equal to producing some 300,000 tons per year, one-fifth of which are in America.

Mr. Willson was trying to reduce lime by carbon, in the electric furnace, in order to produce calcium, with which he expected to be able to reduce aluminum. The accidental discovery that the product gave off an inflammable gas (acetylene) when brought in contact with water, and the subsequent recognition of the calcium carbide by analysis and its industrial production on a very large scale, sounds more like an interesting tale than a solid, commercial fact. It is, however, a fact that the manufacture of calcium carbide has done more to bring the electric furnace and electric methods into industrial prominence, especially in Europe, than any other electrochemical operation. In Europe, in fact, the carbide industry has been woefully overdone, Italy alone possessing enough carbide plants to supply the whole of Europe.

Mr. Willson's small beginnings gave place to the formation of the Union Carbide Co., which controls almost all the production in America. The works at Niagara Falls are under the management of Mr. Price, who was associated with Mr. Willson in his first experiments. The patents to Mr. Willson are U. S. Patents 541,137 and 541,138, of 1895, and 563,527, of 1896; to Mr. Price 572,312 and 572,467, of 1896, and 583,936, of



FIG. 21.—UNION CARBIDE CO.

1897. It is said that the furnaces used are covered also by the patents of Hoovey on a rotating furnace, English Patent 22,521, of 1897, although the circular furnace is said to be originally the invention of Prof. F. B. Crocker, New York.

The works are situated nearly one and a half miles from the power house, above the falls, and are supplied through a conduit with 5,000 horse-power of alternating current at 2,250 volts. The works have the option of taking up to 20,000 horse-power when they want it and the power company are

able to supply it, but the average power which has been used has been close to 5,000 horse-power. The buildings cover 200 by 880 feet of ground, the stock room being three stories in height and ten furnaces are now in operation.

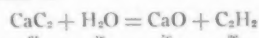
The furnaces are of iron and circular, with a recessed rim, on top of which are bolted segmental wings, 24 inches deep. In the space thus created, the two carbons dip on top of the wheel, and melt the charge of lime and carbon there fed to them. The whole furnace revolves very slowly, about once in twenty-four hours, on trunnions, so that the fluid carbide resulting from the action of the arc is slowly taken out of the field and solidifies in cakes 6 to 9 inches thick, which is taken off the wheel, comparatively cold, at the lower side. The carbons are 6 inches in diameter and are kept about 9 inches apart. The furnace is 8 feet in diameter altogether, 3 feet wide and each takes 3,500 ampères at 110 volts, or 500 horse-power. The output per furnace is about two tons per day.

The materials charged are mixed burnt lime and ground coke, in the proportions of one ton of lime and three-quarters of a ton of coke to produce one ton of carbide, the chemical reaction being



The temperature of formation of calcium carbide is above that of ordinary combustible-heated furnaces, but not very high in the range of electric-furnace work; it is decidedly below that needed for graphitizing carbon or even for producing carborundum. If we consider the energy required to produce a ton of calcium carbide in these furnaces as 6,000 horse-power hours, we can calculate that of the total energy of the current about 45 per cent. is needed to heat the substances to the temperature of carbide formation, 40 per cent. is absorbed in the chemical reactions taking place and 15 per cent. is lost by radiation during the heating (exclusive of heat in hot carbide after removal from the arc).

The ten 500 horse-power furnaces in operation will, therefore, produce 20 tons of carbide daily, using up 20 tons of lime and 15 tons of coke. The carbide, when used, furnishes theoretically 5.5 cubic feet of acetylene per pound, or actually some 5.25 cubic feet, which is 10,500 cubic feet per ton of carbide, and the 20 tons would be equal to 210,000 cubic feet, equal in illuminating power to some 2,940,000 cubic feet of ordinary illuminating gas in illuminating power. The reaction producing acetylene is



and since  $\text{C}_2\text{H}_2$  represents one molecular volume (22.22) of gas, we may say that 64 ounces of carbide produces theoretically 22.22 cubic feet of acetylene and requiring 18 ounces of water.

### THE INFLUENCE OF DIFFUSION IN THE ELECTROLYSIS OF SODIUM CHLORIDE.

By CLINTON PAUL TOWNSEND.

THE electrolytic decomposition of sodium chloride in aqueous solution presents chemical problems of no small degree of complexity. If a body of the dissolved salt be decomposed with insoluble anodes and inert cathodes, the immediate products are chlorine and sodium, the former soluble in brine, the latter oxidized thereby, each product capable of uniting with the other, with the solvent, and with the secondary products formed by reaction of the other with the solvent. Around the anode is formed a saturated solution of chlorine, evolving the excess of gas; from the cathode hydrogen escapes, carrying upward with it and distributing through the solution the sodium hydroxide resulting from the oxidation of the metal. The sodium hydroxide and the chlorine diffuse throughout the solution, and in the regions of contact unite to form sodium hypochlorite, which in its turn diffuses toward both electrodes. At the anode it is in

part oxidized to sodium chlorate, and at the cathode is quickly reduced to chloride; at both electrodes it undergoes electrolysis, the cathode products, primary and secondary, being sodium and sodium hydrate, and those of the anode hypochlorous acid and oxygen. Furthermore, not the hypochlorite only, but the chlorate and the hydroxid submit readily to electrolysis, adding to the complexity of the anode products.

Of these several products, the hydroxid, hypochlorite and chlorate of sodium, and the chlorine, are commercial articles, representing enormous aggregate values in the industrial world; still another compound, sodium perchlorate, has been produced for a hundred years past in the laboratory by electrolytic methods, but is seldom encountered in cells operating upon chloride solutions. For the production of hypochlorites and of chlorates, such disposition of parts is now employed as will facilitate the immediate combination of the products formed at the respective electrodes. For the production of caustic and of chlorine, however, the essential point is to maintain these products apart; to permit the accumulation of the caustic to a reasonable concentration, yet to prevent, so far as may be, its movement by diffusion to or into the anode solution. And surely no more interesting problem was ever offered to the experimenter. The purpose of this paper is to outline briefly, and in their broader aspects, the several lines of attack which have been opened toward a solution of the problem.

If a diaphragm be interposed between the electrodes, the course of the reactions is as above specified, for the phenomena depend largely upon diffusion, which no diaphragm permeable to the current can prevent. Yet a diaphragm modifies to a considerable extent the composition of the final products, for the convection effects, like in kind and at least equal in quantity to those due to diffusion, may be measurably overcome. The diaphragm operates, moreover, to limit the region of contact between the anode and cathode solutions, a fact which forms the basis of some very interesting and quite practicable methods for the maintenance of dilute solutions in a state of reasonable purity, by withdrawing at this point those portions of the solution which have become impure through combination.

The diaphragm may be in contact with one or both electrodes, or at a distance from either; in the latter case the cathode products are necessarily permitted to remain for long periods in contact, through the diaphragm, with those of the anode. Under these conditions diffusion is unchecked, and for this reason no cell of this type has ever attained any considerable measure of commercial success. If the cathode be moved into contact with the diaphragm, and given such open structure as will permit the ready escape through it of the products, of the electrolysis, diffusion proceeds as before, but the electrical resistance is so far reduced that the line between failure and commercial success is crossed; to this type belong the earliest of the operative electrolytic processes for the production of caustic from brine. In such cells the fact of diffusion, and of losses attendant thereon, is frankly admitted, and the resulting hypochlorous acid is usually decomposed in the anode compartment by the regulated addition of hydrochloric acid, often obtained by the direct combustion of portions of the hydrogen and chlorine from the respective electrodes.

In such cells, however, the cathode compartment may be drained, and an increased efficiency is thereby secured. The cathode being in contact with the saturated diaphragm, a thoroughly efficient electrical contact is maintained, and being foraminous it permits the discharge by gravity of the excess of the percolating solution. Its capacity for retaining the caustic solution is, however, far from negligible, and in proportion as it retains such solution it fails to accomplish its proper function of a surface of discharge for the cathode products. The form of the cathode, whether a wire net, a perforated plate, a ribbed plate or a sponge, is thus an essential



point to be determined by an experimental study of its retentive capacity. The claim more recently advanced in favor of a "spongy" or retentive cathode is that the electrolysis proceeds or continues within its interstices; admitting, however, that there exist within the body of the metal such points of potential difference with relation to the anode as will determine therein an electrolytic effect, it will require the clearest of experimental evidence to prove that the electrolyte is sodium chloride and not the more easily decomposable hydrate.

If a compact, spongy or porous, as distinguished from an open cathode, be used, the non-conducting diaphragm is no longer essential to operativeness, for the cathode will itself restrain the flow of the electrolyte and permit the production of caustic of fair concentration. The retention of the diaphragm becomes then a question of expediency, its chief function being to guard the cathode from clogging by deposition therein of the hydrated oxides insoluble in the electrolyte. Seemingly, its use is advantageous, for commercial success has not been attained in its absence.

In diaphragmed cells of whatever type, a considerable apparent increase in efficiency may be secured by converting the caustic as formed into a compound less soluble in the electrolyte, more stable as regards the current or possessing a lower diffusion rate. If such compound represented also an increased value as compared with the caustic and the acid radical which enter into its composition, the increase in efficiency would be real, but, unfortunately, such is not the case, and the method represents in all cases a reduction of values, and can, therefore, be regarded only as an economic retrogression. This, of course, does not mean that it may not also present a margin of profit, simply that the margin of profit is less than if the cell were so constructed as to be capable of yielding the caustic alkali. As types of auxiliary reactions of this character may be mentioned the carbonating of the cathode lyes by carbon dioxide, with the formation of the normal or acid salt; the addition of carbonates of magnesium or of zinc to form double salts; the addition of nitric, manganic and chromic acids; the employment of such solid depolarizers as the metallic sulphates, phosphates, sulphides, etc., and the use of metallic salts in solution as liquid depolarizers, examples being auric chloride, sodium plumbate and the sulphates of iron, copper and zinc. Depolarizing cathodes have also been employed; readily reducible oxides or sulphides which yield their metalloid to the liberated hydrogen. If oxides be used their reduction serves, of course, to dilute the caustic, and if sulphides, the cathode product is no longer the hydrate, but the sulphide of the alkali metal.

The cells which operate on the gravity principle, like those of the diaphragm type, are powerless to overcome the evils of diffusion. In these dependence is placed on the differences in specific gravity between a saturated solution of the salt, and the caustic and chlorine resulting from its decomposition; some devices of quite surprising efficiency have been developed here and abroad, but if it be borne in mind that the rate of diffusion is a function of the concentration of the diffusing solution, and that the amount of diffusion is a function of the time during which given solutions remain in contact, it will be readily understood that such cells necessarily yield weak caustic.

So far as concerns the yield of caustic, the use of insoluble anodes is not material, and it has been attempted to reduce the potential difference between the electrodes and to increase the total value of the final products, by the employment of depolarizing anodes. Iron, zinc, tin, lead and copper have been so used, the salts formed often being precipitated in the anode compartment, or in an external portion of the circulating system, by appropriate reagents, *e. g.*, the lead by regulated addition of soluble chromates, to prevent diffusion toward the cathode. Crude metals, as the alloys of copper and nickel, have been favorite anodes for use in these relations, and the solutions obtained are usually further treated by electrolytic

methods. No process of this character has passed the experimental stage.

Or instead of using a depolarizing anode, the same result may be accomplished by adding to the anode compartment solutions to be chlorinated, or such ores as it is desired to submit to the solvent action of the anolyte. Such methods have, however, introduced such further and unexpected complications as have interfered with the smooth working of the cell.

In addition to the foregoing, two other distinctive methods have been proposed, elaborated through protean forms, and passed into commercial use. As has been pointed out, the real difficulty of the problem lies in overcoming the rapid diffusion of the hydrate through the aqueous solution, and the conception that this might be accomplished by doing away with both solution and hydrate was a basic one. New difficulties arose, however, in the attempt to produce sodium and chlorine directly from the fused chloride; hypothetical "subchlorides," formed at the high temperatures, diffuse as rapidly and with as evil effect as the hypochlorites of the aqueous solution, and for the production of the metal, compounds of lower-melting point, the hydrate and nitrate, have displaced the chloride. The employment of a liquid metal cathode to absorb the sodium as separated has proven, however, a stepping stone to success in the production of the hydrate.

As in the case of aqueous solutions the difficulty to be overcome in cells of the last-mentioned type has arisen from the diffusion into the bath of the cathode product, or, more properly, of the reduction products formed by reaction between the cation and the electrolyte; for the liberated sodium shows no tendency to distribute itself evenly through the body of the molten lead, but crusts it over in a light and rich alloy of intense chemical activity.

The problem has been doubly solved. A supplemental anode of lead, through which a fraction of the total current is shunted, has been used to determine the conjoint deposition of sodium and lead in such proportions as may be desired for the alloy. This method necessarily operates at low efficiency, not only because some 12 per cent. of the current is diverted for the solution of the lead, but because the lead chloride of the bath reacts readily with the separated sodium, the reconstituted sodium chloride representing a direct and serious loss. The second and more rational method consists in preventing the accumulation of the light metal by maintaining the cathode of molten lead in rapid circulation between the region of electrolytic activity and a separate denuding chamber, wherein the sodium is oxidized and the resulting hydrate permitted to stratify. Diffusion is here overcome by reducing the concentration of the diffusing element; the advantage is such as would be obtained in the aqueous method were it possible to remove the hydrate from the cathode at the instant of its formation. Under this mode of operation current efficiencies are high, and such concentration of plant as is indicated by the passage of a current of 19 amperes from each square inch of active anode surface offers alluring economic possibilities. All fused electrolyte methods labor, however, under the disadvantage that the separation of a gram of sodium therein, under conditions of theoretical efficiency, represents the expenditure of nearly double the energy of the same reaction occurring in aqueous solution, under conditions which permit the oxidation of the metal.

The mercury cathode method for the conversion of aqueous chloride into caustic is the precise analogue of the foregoing, and commercially is the successful method of the day. The analogy between those fused and aqueous methods which depend upon the absorption of the cation by a liquid metal is more than superficial, for not only are the methods similar in the form which they have finally taken, but in their historical development they have followed the same course. In the early work the mercury cathode was quiescent, and the objects of the electrolysis were defeated by the combination of the metal



of the light surface alloy with the electrolyte. Thereafter, the necessity for quick dissemination, or, better, for quick denudation, was recognized, and the history of recent construction in cells of this type is largely concerned with the provision of means for effecting the interchange of amalgam between the decomposing and oxidizing compartments. One additional idea has been recently introduced: the conception that means other than mechanical may control the diffusion of the sodium through the mercury. The phenomena of surface tension promise to afford a method of transmitting the alkali metal positively and rapidly through a body of mercury acting as a partition between brine and caustic solutions.

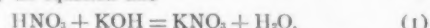
#### ELECTROCHEMICAL THEORIES ILLUSTRATED BY EXAMPLES FROM PRACTICE—I.

IN this serial an attempt will be made to illustrate and explain the modern theories of electrochemical science by examples from practice, and to bring electrochemical science within the reach of the practical man. Each article will be complete in itself. In the first article we will discuss a fundamental principle of the design of galvanic cells. The following experiment, which has been described by Prof. W. Ostwald, is very instructive. Well amalgamated zinc does not dissolve in a solution of sulphuric acid. If, however, an amalgamated zinc rod in contact with a platinum wire is placed into a solution of sulphuric acid, then the zinc dissolves at once with a simultaneous development of hydrogen. Let us begin with a neutral salt solution and suspend in it a zinc rod and a platinum wire, which are in contact at one point outside of the solution; no zinc dissolves; as soon as we add free sulphuric acid the zinc begins to dissolve. Let us change the conditions slightly. Take a vessel with two compartments, which are separated from one another by a porous partition; the zinc rod is placed in the one compartment, the platinum wire in the other; the zinc and platinum are in contact outside of the vessel. Both compartments are filled with a neutral salt solution. We now wish to start the dissolution of the zinc. For this purpose we have to add free sulphuric acid to the neutral solution. Now the question arises: to which compartment have we to add the acid? At the first glance it would seem that as we wish to dissolve the zinc, we have to pour the acid into the compartment containing the zinc; but this would be wrong. By experiment we find that in order to get a lasting dissolution of zinc, we must add the acid to the compartment containing the platinum wire; the zinc dissolves in the one compartment, and in the other compartment hydrogen is developed at the platinum wire.

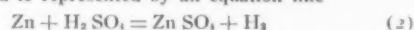
The explanation of this fact will give us a general principle for the design of galvanic cells. Indeed, in our case, we have electrochemical action. If the ends of the zinc rod and of the platinum wire outside of the vessel are not connected directly together, but through a galvanometer, we see that a continuous current flows through the system, from the zinc to the platinum in the solution. We have here a change of chemical energy into electrical energy; in other words, we have a galvanic cell. The problem is, therefore: why is this cell active only if the acid is added to the solution at the platinum side, and not at the zinc side? The discussion of this problem will first lead us to point out the characteristic property, which distinguishes those chemical equations which can represent electrochemical action, from those which cannot represent electrochemical action. Afterwards, we will assume a reaction which can represent electrochemical action, and will discuss the particular conditions under which, in this reaction, chemical energy is changed into useful electrical energy. We will begin with some general remarks on chemical equations.

The most concise and exact way of describing a chemical process is by means of a chemical equation. That chemical equations have a simple form, is a result of the experimental

fact that elementary substances combine in constant multiple proportions. Thus, the neutralization of an acid by a base is represented by an equation like



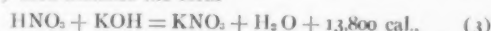
which equation states that one gram molecule  $\text{HNO}_3$  (63.05 gram), and one gram molecule  $\text{KOH}$  (56.16 gram), are changed into one gram molecule  $\text{KNO}_3$  (101.19 gram), and one gram molecule  $\text{H}_2\text{O}$  (18.02 gram). The solution of a metal in an acid is represented by an equation like



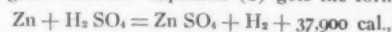
which equation states that one gram molecule  $\text{Zn}$  (65.4 gram) and one gram molecule  $\text{H}_2\text{SO}_4$  (98.08 gram) give one gram molecule  $\text{ZnSO}_4$  (161.46 gram) and two gram atoms  $\text{H}$  (2.02 gram). This is the way in which the chemical equations are generally understood by chemists; the transformation of matter only is considered, and the combining proportions of the different materials, involved in this transformation, are given by the chemical equation.

If, however, a chemical process is considered from a broader and wider point of view, then there is not only a transformation of matter, but at the same time always a transformation of energy. If the changes of energy are taken into account, there do not exist any chemical processes pure and simple; that means: any chemical process in a system of reacting bodies (which system is supposed to be separated from the outside) represents either a gain or a loss of chemical energy in the system, and thus, according to the principle of conservation of energy, must involve a loss or a gain of some other kind of energy. The principal forms of energy into which chemical energy is changed in practice, are heat and electrical energy; one speaks, therefore, of thermochemical and of electrochemical processes.

The energy changes can also be easily represented by equations, when an additional meaning is given to the ordinary chemical symbols. Thus,  $\text{HNO}_3$  represents, as before, a certain mass; if we measure all the masses in gram molecules, it represents 63.05 gram; but we now assume that it also represents a certain energy, namely, the intrinsic chemical energy stored up in 63.05 gram of the chemical compound  $\text{HNO}_3$ . We assume that the intrinsic energy of all the elements in the free state is zero; then the intrinsic chemical energy stored up in 63.05 gram  $\text{HNO}_3$ , represents the energy corresponding to the change of 1.01 gram  $\text{H}$ , 14.04 gram  $\text{N}$ , and 48 gram  $\text{O}$ , into 63.05 gram  $\text{HNO}_3$ . If we understand the chemical symbols in this way, the ordinary chemical equations, like (1) and (2), do not balance any more; because the chemical energy stored up in the materials at the beginning of the reaction, does not equal the chemical energy stored up in the materials at the end of the reaction. Thus, we know that when the processes (1) and (2) take place from the left side to the right side, both processes evolve energy; and if, according to our assumption, the masses of the chemical symbols represent gram molecules, then the energy evolved by each process has a certain distinct numerical value which has been determined by experiment. Energy can be measured in gram calories, watt seconds, gram centimeters, or any other unit which one may choose. The energy evolved or absorbed by a certain chemical process is generally given in gram calories, as it is determined from thermochemical measurements. The equation (1) then assumes the form



i. e., when in an aqueous solution one gram molecule  $\text{HNO}_3$  and one gram molecule  $\text{KOH}$  change into one gram molecule  $\text{KNO}_3$  and one gram molecule  $\text{H}_2\text{O}$ , energy is evolved equal to 13,800 gram calories. Equation (2) gets the form



i. e., when one gram molecule  $\text{H}_2\text{SO}_4$  in aqueous solution dissolves one gram atom  $\text{Zn}$ , to form one gram molecule  $\text{ZnSO}_4$  and 2 gram atoms  $\text{H}$ , energy is evolved equal to 37,900 gr. cal.

Instead of giving the energy value in gram calories, we

may just as well give it in watt seconds, as there is a constant relation between both units:

$$1 \text{ watt second} = 0.241 \text{ gram calorie,}$$

$$1 \text{ gram calorie} = 4.155 \text{ watt seconds,}$$

so that it is easy to go over from gram calories to watt seconds. But this formal change from the heat unit of energy to the electrical unit is evidently useful and judicious only if we know that the chemical equation represents an electrochemical action.

Now the important question naturally arises: can any chemical equation represent an electrochemical action? It will be shown that this question must be answered in the negative. For instance, it will be shown that of the above chemical reactions—both of which evolve energy—equation (1) can never by itself represent an electrochemical action, while equation (2) can represent an electrochemical action. What, then, is the characteristic feature of those chemical equations which can represent electrochemical action?

We know that whenever electrochemical action takes place—either in a cell into which current is sent from the outside, or in a galvanic cell, which gives out current—the strictly electrochemical action takes place at the electrodes. We may say in general that we have always reduction at the cathode and oxidation or perduction at the anode. The term "perduction" has recently been suggested by J. W. Richards, instead of oxidation, because the latter term would seem to indicate a combination with oxygen, which is not always the case when we have perduction. The characteristic feature of reduction and oxidation, or perduction, is that there is a change of valency. The amount of material reduced at the cathode and the amount of material oxidized or perduced at the anode are directly given by Faraday's law; and as the latter is the fundamental law of electrochemical action, it is evident that there must be reduction and oxidation, whenever there is electrochemical action. In the experiment described above, zinc goes into the solution; from the uncombined state it goes over into the sulphate, it gains "bonds," in other words it is "oxidized," or perduced. At the other end, at the platinum wire, hydrogen leaves the solution; from the state of combination with  $\text{SO}_4$  it goes over into the uncombined gaseous state, it loses "bonds," in other words, it is reduced. This example will show what is meant here with reduction and oxidation; a more detailed discussion of this matter will be given in a future article. For the present it is sufficient to state that only those chemical equations can represent electrochemical action which represent oxidation and reduction. This is the case for equation (2), as just explained, but it is not the case for equation (1). In equation (1) H and K simply exchange their places, but *without any change of valency*. For this reason it is evident that under no circumstances equation (1) by itself can represent electrochemical action; of course, the process represented by (1) may take place as *part* of the whole process occurring in an electrochemical system, but it can never represent the total electrochemical process.

Now take the reaction of equation (2). We know it can represent electrochemical action. But this does not mean that under all circumstances we get the chemical energy lost during this reaction in the form of useful electrical energy. For instance, when we put unamalgamated zinc into sulphuric acid, equation (2) again represents the action, but in this case we get heat instead of electrical energy. It is evident that to change the chemical energy into useful electrical energy, we must arrange our system properly; and this leads us back to Ostwald's experiment described above. We saw that in the arrangement described it was necessary to add the acid to the compartment at the platinum wire. The reason will now become clear; we always must arrange our system so that the substance to be reduced is at the one electrode and the substance to be oxidized is at the other electrode. If we bring both substances together directly, the chemical energy is changed into heat. If we want to get useful electrical energy,

we have to keep them separated, and have to place the substance to be reduced at the one electrode, and the substance to be oxidized at the other electrode. That is why Ostwald speaks of "chemical action into the distance." In our case, while the cell gives out current, zinc is dissolved, *i. e.*, oxidized, and hydrogen is reduced from its combination in  $\text{H}_2\text{SO}_4$  to free hydrogen. Hence the sulphuric acid must be placed at the platinum.

This principle appears now to be self-evident, but it has not always been so, and many inventors, in designing batteries, have made the mistake of bringing the substances to be oxidized and to be reduced directly together; the result is always in such cases that a strong chemical action occurs, but that heat is developed instead of electrical energy.

We will briefly illustrate our principle by a few examples. In the Daniell cell we have the reaction



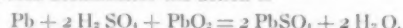
Zn is oxidized, Cu is reduced. The Zn and  $\text{CuSO}_4$  must be kept separately; this is done by using a double fluid cell, the Zn being placed in a solution of  $\text{ZnSO}_4$  or  $\text{H}_2\text{SO}_4$ .

In the Bunsen cell, with Zn in  $\text{H}_2\text{SO}_4$ , and C in  $\text{HNO}_3$ , Zn is oxidized and N is reduced; hence the Zn and  $\text{HNO}_3$  are kept separately; one of the possible reactions is



In the same way, in the chromic acid battery we must keep the chromium solution away from the zinc.

In the lead accumulator the action is



the spongy lead at the one side being oxidized to lead sulphate, and the lead peroxide being reduced to lead sulphate at the other side.

In the new Edison battery we have the reaction



the nickel being reduced and the iron oxidized.

Everything in Ostwald's experiment, which seemed peculiar, can now be explained. Amalgamated zinc does not dissolve in a solution of sulphuric acid; it represents a single electrode, and this is no electrochemical system. But if this zinc is in contact with a platinum wire, we have an electrochemical system, we have a short-circuited cell, hence the zinc will dissolve. If we use the vessel with the two compartments separated by a porous partition, then one compartment will have to represent the anodic compartment, and the other the cathodic compartment; in the former we have to place the zinc, which is to be oxidized, and in the latter the acid, as the hydrogen is to be reduced. The neutral salt solution around the zinc furnishes the ionic mechanism by which the "chemical action into the distance," *i. e.*, the reduction and oxidation at both ends, is made possible.

## GRAPHITE ELECTRODES IN ELECTROLYTIC WORK.

By C. L. COLLINS, 2D.

THE relative value of graphite and other forms of electrode material in the various lines of electrolytic work has already been discussed thoroughly, and the results of numerous comparative tests published. These results, obtained both in experimental test and actual practical work, may be briefly summarized as follows:

In the electrolytic decomposition of chloride solutions, in the manufacture of chlorine and caustic alkalies, in the chlorination of gold ores, in the recovery of nickel, zinc, etc., graphite electrodes used as anodes possess a life from two to four times as great as that of the best crude-retort carbons, and from four to seven times that of the various makes of manufactured amorphous carbons, such as those made from mixtures of a pitch bond and powdered petroleum coke or lamp-black, etc. In consequence, the graphite electrodes are rapidly replacing all such forms in this line of work, and are even

proving more efficient and economical than platinum, on account of the excessive cost of the latter material. In electrolytic processes, however, where the anode is subjected to a more active oxidizing action, such as in the manufacture of chlorates, the deposition of metals from sulphate solutions, in the oxidation of chromic acid solutions, etc., the differences between the action of graphite and amorphous carbon, although still very much in favor of the former, are not so great, and both suffer considerable disintegration. In chlorate work platinum and platinum-iridium alloys are still extensively used as anodes.

In alkaline-cyanide solutions, in the recovery of gold and silver from its ores, iron anodes have generally been used, and in some cases platinum; but serious corrosion with the former, and the expense of the latter, have been decidedly disadvantageous. Here also the graphite electrode is proving successful. Although there is a slight coloring of the solutions with such electrodes, absolutely no corrosion is apparent, and with the proper current densities there is very little disintegration. The coloring of the solution prevents the use of graphite electrodes in electroplating with gold or silver in cyanide solutions, as here the deposited surface must be seen and examined during the operation, but in processes for the recovery of metals from their ores this element need not be taken into consideration.

The processes mentioned above represent the largest fields of electrolytic work in which graphite electrodes are now being used; but actual comparative tests which are being made in other, and newer lines of work continually prove that the value and usefulness of this material to the electrochemical industry is still to be fully appreciated. All tests to which graphite has been subjected, however, have dealt purely with its chemical properties, or its ability to withstand, for a longer or shorter period, in comparison with other materials, the action of certain electrolytes. The results thus obtained do not in themselves give a true basis for comparison, for the ease with which graphite can be handled, its *adaptability*, purity, high electrical conductivity and other *physical* characteristics, should be given equal consideration. It is conceivable that these latter might in certain processes more than offset the single advantage of longer life possessed by some other form of electrode material.

Graphite electrodes can be machined with the greatest ease, and it is to touch upon this characteristic, and the consequent adaptability of graphite electrodes to almost any conditions, that this paper is written. Ease of machining, however, can be said to apply only to electrodes manufactured by the Acheson process. With this process all electrochemists are familiar, and a description of the method of graphitizing employed is unnecessary.

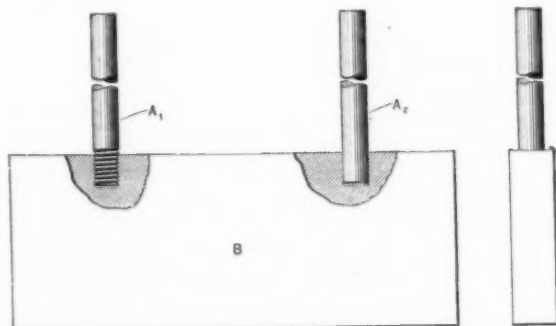


FIG. 1.—GRAPHITE ELECTRODE.

In electrolytic work the size and shape of the electrode is determined more in reference to a certain surface area desired than to the cross section necessary to carry the total current used. For mechanical strength the electrode must be given a fair thickness, in proportion to its width, and with the low-

current densities of practical electrolytic work, the carrying capacity of its cross section is never approached. It is, therefore, of importance to design an electrode which will give a large surface area, with a minimum volume, and whose surface area will not decrease appreciably as slow, gradual disintegration takes place, assuring fairly uniform current densities. The ease of machining graphite electrodes, or their extreme adaptability, makes such forms possible.

In Fig. 1 is shown a form of anode consisting of a graphite slab *b*, into one edge of which are fitted graphite rods *a*<sub>1</sub>, *a*<sub>2</sub>, etc. These *leading-in* rods can be as many, or as few, as desired, and are designed to utilize the full electrical conductivity of graphite articles. They serve both as means of support for, and as the electrical conductors to, the slab *b*, or anode proper. The rods may either be threaded into the slab as *a*<sub>1</sub>, or both the rod and the hole in the slab may be given a slight taper and a tight, drive fit made as in *a*<sub>2</sub>. In Fig. 2 the slab is shown suspended vertically in the electrolyte.



FIG. 2.  
GRAPHITE ELECTRODE.

making a tight seal around the small rods where they pass through the cover of the cell. With the slow, gradual disintegration of the slab *b*, its surface remains fairly constant. To prevent any creeping of solution up through the rods or a possible escape of gases through the same, which might act on the metal conductors, the rods can be impregnated with paraffine.

If for any reason it is absolutely essential that connection with the metal conductors be made inside the cell, instead of casting a metal head to the end of the electrode, which must be re-cast every time the electrode is removed, a round graphite electrode can be used, which can be threaded on the end and screwed into a tapped hole made in the cast head. Electrodes can then simply be screwed into the same cast head as it becomes necessary to renew them.

The methods mentioned above have already proved very successful in actual electrolytic work upon a practical scale. Other forms even more complex are being used, which would have been wholly impossible with the old style of amorphous carbon electrodes. Although the style of anode shown is the simplest possible form, and is applicable to practically any process, special conditions might require other methods of machining and assembling. It is hoped, however, that with the above practical illustrations, other forms will suggest themselves which may be the most suited to the special work of the experimenter in question.



## ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

UNITED STATES PATENTS ISSUED JULY 1, 1902.

**No. 703,420.** Filed August 1, 1899; Rudolph M. Hunter, Philadelphia, Pa. Process of making accumulator plates.

The inventor casts a lead framework around segments of coiled or folded strips of lead, which he cools during the process with a stream of air, claiming to produce a "mechanically integral structure." To really accomplish this object would require not only the actual fusion of the segment of coiled lead at the points of union, but also either a flux or reducing agent to remove the film of lead oxide that is inevitably present. The wording of the specification indicates that the inventor does not intend to actually fuse the edges of the strips. It seems doubtful whether this method can compare favorably in cheapness with many of the well-known methods of making (by rolling or punching a plate), which consists of an integral structure of ribs and thin laminae.

**No. 703,490.** Filed July 13, 1891; Malcon O. Smith, Depew, N. Y. Storage battery.

This battery consists of a cup-shaped cell of lead, the outside of which forms one pole and the inside the other pole. The form is adapted for the piling up of several cells in series and is very similar to that of G. Philippart, patented January 29, 1884 (No. 292,762).

**No. 703,541.** Filed January 22, 1891; C. C. Clark, Philadelphia, Pa. Water purifier.

An electrolytic tank inserted within a larger settling tank. Water is admitted through the electrolytic tank, where it is electrolyzed between perforated copper, platinum or iron electrodes; thence it passes into the settling tank. The settling tank is provided with tubes for cooling or heating, as the case may require, and with a dome for the collection and elimination of gases and lighter impurities. Details of construction.

**No. 703,623.** Filed June 26, 1891; Theodore F. Taylor, Camden, N. J. Electroplating apparatus.

Details of construction are claimed for a rotatable drum, in which small articles are tumbled and plated simultaneously. There is a fixed anode and a cathode of revolving rings.

**No. 703,673 and 703,674.** Filed September 13, 1899; Elmer A. Sperry, Cleveland, Ohio. Assignee, National Battery Co. Electric battery and mounting same. Connection for batteries. Mechanical construction of battery jar or receptacle.

**No. 703,857.** Filed August 6, 1891; C. J. Tossizza, Paris, France. Electrometallurgical treatment of zinc ores and especially blend.

This patent is to provide a method for depositing zinc from solution by the joint action of electrolysis and a chemical reducing agent. The reagent employed is sulphurous acid. In order to prevent the reduction of sulphurous acid to sulphur or hydrogen sulphide, he makes two separate operations; one operation in which copper is dissolved and zinc deposited, the e. m. f. being  $2.30 - 1.21 = 1.09$  volts; the other operation in which copper is redeposited and  $\text{SO}_2$  oxidized to  $\text{SO}_3$ . It is claimed that the two operations combined require only from 1.4 to 2 volts.

Such a double cycle has certain disadvantages. One which would be practically very great, is the introduction of copper into the electrolyte without contaminating the deposited zinc. The patentee does not state whether he prevents this by porous diaphragms or in any other way.

**No. 703,861.** Filed March 5, 1891; A. A. Vogelsang, Dresden, Germany. Electrolytic cell and electrode therefor.

"The object of the invention," as stated by the inventor, "is primarily to enable all-platinum electrodes to be used economically." Parallel electrodes of platinum foil, not connected

to any source of current except the electrolyte, are so disposed in a trough that the electrode flows in a zigzag path over one and under the next from one end of the trough to the other. The terminal electrodes only are connected to a source of current. A portion, at least, of the current will evidently traverse the solution from end to end, entering and leaving only the terminal electrodes. Whether the total current will take this path or a part of it go through the suspended intermediate electrodes will depend on the electromotive force employed and the nature of the electrolyte.

**No. 703,875.** Filed March 14, 1901; Walter E. Winship, San Francisco, Cal. Active material for storage batteries and process of making same.

Lead oxides are mixed with water and glycerine into a paste, which sets quickly and firmly. This is reduced to spongy lead electrolytically in a bath of a fixed alkali carbonate. It is claimed that the slight solubility of the paste in the alkali carbonate causes the lead to "tree" in parallel crystals and form a mass of greater porosity and other desirable properties. It seems that some of the claims would cover broadly the well-known process of reducing lead chloride to metallic lead electrolytically, as for example, claim 1: "The process of forming an active material for storage batteries consisting in suitably binding a mass of lead salt which will retain its configuration after immersion, and reducing it by electrolysis to spongy lead in an electrolyte which is a solvent for the lead salt, and from which solution lead trees essentially parallel to each other are plated within the mass."

**No. 703,895.** Filed October 18, 1900; A. F. Clark, Philadelphia, Pa. Separator plate for secondary batteries.

The separator plate consists of hard rubber in the general form of a window blind with outwardly and upwardly projecting slats, forming pockets with the adjacent face of the positive plate, in which active material is retained and prevented from falling to the bottom of the cell.

UNITED STATES PATENTS ISSUED JULY 8, 1902.

**No. 704,010.** Filed May 23, 1898; Thomas A. Edison, Llewellyn Park, N. J. Apparatus for concentrating magnetic iron ores.

This is a combination of pulverizing rolls, screens, drums, magnetic separators and conveyors.

**No. 704,125.** Filed July 20, 1891; W. T. Seddon, Minersville, Pa. Battery.

Mechanical details of structure of a battery consisting of zinc and carbon electrodes, the carbon electrodes being hollow and containing "chrome-salt solution." No electrolyte is mentioned except the "chrome-salt solution."

**No. 704,252.** Filed July 30, 1901; Henry K. Hess, Philadelphia, Pa. Process of making plates for storage batteries and product thereof.

Active material is molded into the form of a plate and at the same time molded around the conducting metal strips by means of pressure. Details of the mold are described.

**No. 704,303.** Filed January 8, 1901; Thomas A. Edison, Llewellyn Park, N. J. Reversible galvanic battery.

This battery comprises an oxide of mercury anode and a cathode of zinc, deposited upon metallic magnesium, the electrolyte being an alkaline solution. The oxide of mercury is mixed with flake graphite and confined in a perforated nickel receptacle. The general construction of this receptacle has been described by the inventor in previous patents, particularly in an application filed October 31, 1900. The advantage claimed for oxide of mercury is that no particles of the oxide, when reduced and in contact with the zinc, produce local action.



They merely amalgamate the zinc instead of producing local action. In this connection the inventor says: "with almost every other oxygen-storing element of which I have knowledge, infinitesimal amounts thereof are dissolved in the alkaline solution and produce objectionable local action on the zinc."

The use of metallic magnesium, on which zinc is deposited, as an accumulator plate, is singular, as it would seem that the highly electropositive properties of magnesium render it extremely liable to oxidation. This is particularly true when it is amalgamated; an amalgamated strip of magnesium in contact with pure water is rapidly converted into magnesium hydrate with the evolution of hydrogen gas. The use of oxide of mercury as a positive element instead of lead peroxide, requires about the same weight of material for a given capacity in ampere hours.

**No. 704,304.** Filed March 1, 1901; Thomas A. Edison, Llewellyn Park, N. J. Reversible galvanic battery.

The object of this patent is to claim specifically oxide of cobalt ( $\text{Co}_2\text{O}_3$ ) as a depolarizer in an alkaline reversible galvanic battery. The oxide of cobalt is mixed with graphite or other flake-like conducting substances. Oxide hydrate or dioxide of cobalt is prepared in the usual way by precipitation. After drying, powdering and pulverizing very finely, it is mixed with one-seventh of its weight of graphite. Finely-divided iron is mentioned as the negative plate.

**No. 704,305.** Filed May 17, 1901; Thomas A. Edison, Llewellyn Park, N. J. Electrode for storage batteries.

Claims a receptacle for active material for a storage battery, comprising a pocket of perforated and corrugated metal with a support for the same. It is found necessary in a battery of the iron-nickel-alkaline type to retain the active material in close contact by means of pressure with the conducting support. Perforated metallic cases or pockets of very thin sheet steel, plated with nickel, have not sufficient rigidity to maintain an intimate contact by pressure under the influence of expansion and contraction due to charging and discharging. By corrugating the perforated metal, however, the rigidity of the receptacle is greatly increased, as well as the amount of expansion it will undergo without exceeding the limit of elasticity.

**No. 704,306.** Filed July 20, 1901; Thomas A. Edison, Llewellyn Park, N. J. Reversible galvanic battery.

The claims cover specifically the combination of finely-divided copper negative plate and nickel or cobalt oxide mixed with flake graphite as a positive plate in an alkaline solution. The construction is substantially the same as the Edison nickel-iron battery with the substitution of finely-divided copper for the iron. It is stated that oxide of cobalt is not as desirable for this use as oxide of nickel, "owing to the greater cost and to the fact that it is slightly soluble in the alkaline electrolyte." Both active materials are intimately mixed with an inert flake-like conducting substance, such as flake graphite, to increase the conductivity of the cell. Pure carbonate of copper is reduced by hydrogen at the lowest possible temperature, not exceeding  $500^\circ$  Fahrenheit for six or seven hours, until the copper is converted into its black oxide. The inventor states that unless the copper is in a very finely-divided form throughout, a soluble blue salt is produced, which results in local action and rapid deterioration of the elements. The nickel hydrate is prepared in a non-colloidal form by adding to a boiling solution of nitrate of nickel a sufficient quantity of magnesium hydroxide to precipitate the nickel as hydroxide.

**No. 704,349.** Filed March 15, 1901; Eugene Leconte, Estaires, and Jerome Loiselet, Paris, France. Process of manufacturing rice starch or other amylaceous substances.

The rice or other grain, after washing and soaking in a dilute alkaline solution, and after being finally washed with pure water, is ground into a paste, diluted and rendered alkaline by sodium carbonate to the extent of one gram of soda per

liter. The object of the sodium carbonate is to produce electric conductivity and to assist in removing the gluten. The solution is then electrolyzed in tanks with "electrodes of aluminum, zinc or any other suitable matter." The action of the current precipitates gluten and other organic matters, leaving the starch practically pure.

**No. 704,393.** Filed February 27, 1901; Albert Simon, Bordeaux, France. Manufacture of iron, manganese and alloys of these metals by aid of electricity.

The material is dissolved in fused calcium fluoride in an electric furnace of special construction. The iron, manganese or alloy is deposited electrolytically on the cathode by a continuous current. The inventor states that the "silicon reduced under the action of the current combines with the free fluorine to form the gaseous fluoride, which is set free, so that the metal only retains but small quantities of silicon." How the fluorine set free at the anode combines with the silicon liberated at the cathode, thus chemically removing the reduced silicon from the reduced iron or manganese, is not explained by the inventor.

**No. 704,399.** Filed December 16, 1895; Julius Taluau, Philadelphia, Pa. Stained-glass window or similar object, and process of making same.

**No. 704,400.** Filed June 30, 1897; Julius Taluau, Philadelphia, Pa. Method of framing glass.

**No. 704,401.** Filed March 22, 1898; Julius Taluau, Philadelphia, Pa. Method of framing glass.

These three patents all relate to improved methods of uniting small pieces of glass into an ornamental framed plate. Plates of this kind have heretofore been made by running strips of lead between the adjacent pieces of glass and soldering at the joints. By the electrolytic process the pieces of glass are laid upon a conductor, such as a sheet of lead with spaces between for the electrodeposition of copper. The pieces of glass may be fixed in place by means of wax. The plate is then placed in a bath of copper sulphate as a cathode, the deposited copper filling the spaces between the pieces of glass and uniting the whole into a rigid substantial frame. By this process the most intricate designs composed of very small pieces may be united at very little expense.

#### UNITED STATES PATENTS ISSUED JULY 15, 1902.

**No. 704,639.** Filed September 27, 1899; Carl Hoepfner, Frankfurt-on-the-Main, Germany; Henry Orth, Jr., administrator. Leaching and extraction of metals from their ores.

The improvement covered by this patent over previous processes of Hoepfner for extracting copper from sulphide and other ores, consists in the use of a solution of cupric chloride in a non-saturated solution of sodium chloride. Instead of the quantity of chloride of sodium which would saturate the solution the inventor uses from one-quarter to three-quarters of this quantity. He finds that cupric chloride solutions containing less than the saturating quantity of chloride of alkali or alkaline earth metals can be made more concentrated in cupric chloride. When heated to from  $60^\circ$  to  $100^\circ$  C. these solutions are very active solvents of copper, copper sulphide, silver and other associated metals with formation of cuprous chloride, also of cuprous chloride, lead chloride or silver chloride, which are rendered partially insoluble by cooling, thus offering a very easy means of separating these salts.

**No. 704,649.** Filed June 25, 1895, and October 30, 1901; Hudson Maxim, Brooklyn, N. Y. Electrical furnace for treating highly-refractory substances.

A special form of rotating horizontal tubular electrical furnace, having a screw feed for forcing the material to be operated upon into the furnace at one end and out at the opposite end. A peculiar feature of this furnace is a fused lining of material, having greater specific gravity than that of the material treated. This fluid lining is maintained by cen-

trifugal force in its position in the form of a liquid tube surrounding the material to be operated upon. The furnace is intended particularly for the production of calcium carbide.

**No. 704,673.** Filed July 27, 1901; David H. Browne, Cleveland, Ohio, and Thomas M. Niel, Toronto, Can. Process of recovering metallic tin.

Scrap tin and ores of tin are treated with a solution of ferric chloride, heated and slightly acidulated. The tin is dissolved and the ferric chloride reduced to ferrous chloride. The second step in the process is the deposition of the tin electrolytically from the solution at the cathode and the reoxidizing of the ferrous chloride to ferric chloride at the anode. A porous diaphragm is used to separate the anolyte from the catholyte. The solution is first used as a catholyte, from which the tin is deposited, leaving iron as ferrous chloride. This solution then becomes the anolyte and is reoxidized to ferric chloride.

**No. 704,739.** Filed October 3, 1900; J. B. Entz, Philadelphia, Pa. Secondary battery.

The object is to produce a lighter accumulator for automobiles. A special form of corrugated grid of antimonial lead provided with projections or perforations for holding the active material is employed. The plate is constructed of rolled antimonious lead, which, it is claimed, becomes malleable by reason of the rolling. Eight per cent. of antimony is recommended. This material does not oxidize under the action of the battery and is, therefore, durable, "retaining its initial strength during the existence of the plate."

**No. 704,744.** Filed April 28, 1902; Herman Heinicke, Schoenberg, near Berlin, Germany. Electric accumulator.

A special form of grid or support for the active material, consisting of a conducting base with angular grooves extending from top to bottom and horizontal strips which assist in retaining the active material.

**No. 704,751.** Filed July 30, 1901; Harold M. Martin, Philadelphia, Pa. Manufacture of secondary-battery plates of the Planté type.

This patent claims broadly the process of rapidly forming a storage-battery plate by electrochemical means and controlling the temperature, particularly by keeping the temperature of the electrolyte below 115° Fahrenheit. This is done "by abstracting heat from it" when its temperature increases. There are many processes in common use for forming active material electrochemically which generate heat and cause an increase of temperature. The abstraction of heat seems to be the only possible way of keeping the temperature down and is the method always used. The novelty of such a process as cooling an electrolyte by abstracting heat from it is not apparent.

**No. 704,759.** Filed July 29, 1901; Hugh Rodman, Philadelphia, Pa. Storage-battery separator.

The combination of storage-battery plates with an impermeable wooden diaphragm between each pair of plates, said diaphragm having acid wells both sides thereof in a substantially vertical position. The object of this separator is to provide a free circulation of the acid from the top to the bottom through vertical grooves or wells cut on the sides of a wooden sheet. These grooves may be parallel on both sides or those on one side may cross grooves on the opposite sides at a small angle. The latter arrangement would probably give greater stiffness and durability. Any kind of wood may be used, but porous or fibrous wood is particularly recommended. It is stated that diaphragms of wood possess unique and remarkable properties which adapt it for the purposes. The remarkable properties mentioned are efficiency, durability and capacity.

**No. 704,767.** Filed September 29, 1900; Edward G. Steinmetz, Philadelphia, Pa. Secondary battery.

The object of this invention is to avoid the casting of lead chloride and its detrimental effect upon the health of the workmen, also to avoid the production of blow holes. A crystalline structure is imparted by subjecting the mass of lead oxide or lead salts to electrolytic action in a bath capable of dissolving it, the salt or oxide going into the solution and immediately re-depositing it in a metallic state of crystalline structure, without any substantial change of external form of the mass. The material is first molded or stamped into blocks or cakes. A lead grid is cast around these cakes in the usual manner. The plate is then used as a cathode in an electrolyte, in which the lead salt or compound is insoluble. The improvement consists in stamping or molding the material instead of casting it into cakes or blocks. In all other respects the process and results are identical with others in use; such, for example, as the well-known "chloride" battery plate, the cast-lead chloride being soluble, as well as the molded.

**No. 704,831.** Filed June 1, 1901; Charles B. Jacobs, East Orange, N. J. Process of manufacturing sulphuric acid from sulphur dioxide in aqueous solutions by electrolysis.

Claims the process of making sulphuric acid by passing sulphur dioxide through a porous anode and setting free the oxygen of water upon said anode. A horizontal porous conducting plate, cemented into a jar, forms a partition dividing the upper part of the jar from the lower. Sulphur dioxide is admitted below this partition and is caused to pass through the pores into the upper chamber containing sulphuric acid. The temperature is maintained by refrigeration at zero centigrade, in order to secure a concentrated solution of sulphur dioxide. Strong acid is produced and is drawn off when it reaches the proper strength, as indicated by a hydrometer. A pressure of 2 volts and a current density of 15 to 20 amperes per square foot anode surface is used. The inventor states that 500 amperes will produce one ton of 50° Baumé sulphuric acid in three hundred and three hours, with a theoretical efficiency of 54 per cent. There seems to be some mistake here, as this quantity of electricity would produce only 203 kilograms or 450 pounds of concentrated sulphuric acid, while one ton of 50° Baumé acid would contain 1,240 pounds of the concentrated acid. Pure SO<sub>2</sub> is obtained by saturating water with the gas at the freezing point, under which condition H<sub>2</sub>SO<sub>4</sub>, 14H<sub>2</sub>O are separated, leaving the impurities of the gas behind.

**No. 704,859.** Filed November 21, 1901; Victor Cheval and Joseph Lindeman, Brussels, Belgium. Electric accumulator-electrode.

A form of construction in which the negative plate consists of a single mass, having vertical cylindrical or prismatic holes, into which a number of positive electrodes in the form of rods are inserted.

**No. 704,993.** Filed January 8, 1900, and May 16, 1902; Frederick C. Weber, Chicago, Ill. Electric smelting furnace.

A vertical tubular furnace, having numerous electrodes in the form of rods arranged radially and adapted to produce arcs within the tubular furnace chamber of varying intensity at different points and subject to regulation.

#### UNITED STATES PATENTS ISSUED JULY 22, 1902.

**No. 705,076.** Filed February 19, 1902; Charles M. Hall, Niagara Falls, N. Y. Manufacture of carbon electrodes.

A furnace for baking carbon electrodes, particularly such as are to be used for the electrolysis of fused baths. The carbons are placed in proximity to an electrically-heated carbon core and insulated therefrom, the object being to prevent as much as possible of the current from passing through the carbons themselves and to develop the heat in the carbons gradually by radiation. It is claimed that carbons thus produced are of greatly improved quality.

[Lack of space requires that several patents issued in July be reserved for the next issue.]

## SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

*A Summary of all Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.*

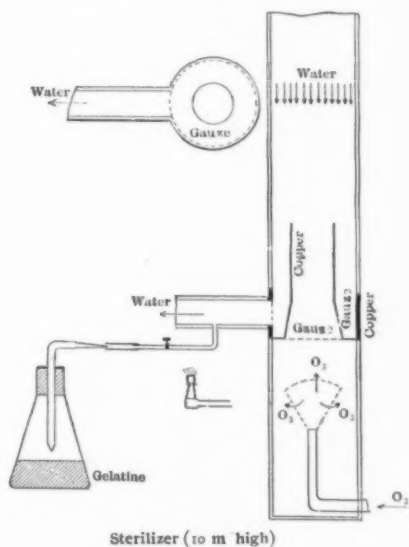
By CARL HERING.

### INDUSTRIAL ELECTROCHEMISTRY.

**Metal Refining.**—A good process may readily be a commercial failure if it is not properly carried out from the industrial standpoint, while, on the other hand, a poor process may sometimes, by good design of the installation and good management, be made a commercial success. As so much depends on the proper design and arrangement of such installations, an article by PHILIP, begun in the *Lond. Elec.*, August 1st, and containing many statistics and formulas, will, no doubt, be of interest to those who have the responsibility of designing plants for electrolytic metal refining, as he has for many years past collected and tabulated all the available details of such installations, in order to elaborate a connected scheme by means of which the task of designing an electrolytic refinery upon a sound financial basis might be successfully undertaken. The general method which he adopted was to endeavor to arrive at a formula for every item of outlay, expressing it in terms of all the variables involved, and then to insert in this a constant or constants obtained by calculation from all the available and trustworthy figures hitherto published with regard to the particular item of outlay under consideration. For instance, the power employed in an electrolytic copper refinery must vary directly with the number of tons output per year, when the current density is kept constant; while, on the other hand, if the output is kept constant, then if the current density is doubled (neglecting the back e. m. f. at the electrodes, which is small and constant) the voltage must also be doubled, while only half the total number of vats will be used; hence the power required must be doubled. He thus arrives at a formula stating that the cost of the power plant must be proportional to the product of the annual output of refined copper and the current density. This, of course, applies only to such cases in which the counter e. m. f. may be neglected. He then takes up in detail the problems of the establishment of an electrolytic copper refinery. The first point is the amount of capital available, the other important points are current density, area of ground, tons of copper to be refined per year and profit available per year; the current density is always the ruling factor. Taking up first the capital expenditure, the cost of offices in pounds sterling is given as  $150 + 1 \cdot 10$  the number of tons refined per year. The area of refinery buildings for a given yearly output is inversely proportional to the current density; the area in square feet is given as 30 times the ratio of the number of tons refined per year to the current density in amperes per square foot; the constant 30 is an average value, in six different plants it varied between 21.9 and 31.5. The cost of the buildings in pounds sterling is given as 7.5 times the ratio of the output in tons per year to the current density in amperes per square foot. The power required varies directly as the output per year and also directly as the current density employed. If gas engines with gas producer plant are installed, and if the prime cost of supply and erection of this plant is \$60 per horse-power installed, then the prime cost of the plant in pounds sterling, including the erection of gas engine and producer plant, may be fairly given as 0.12 times the product of the output in tons per year and the current density in amperes per square foot.

**Sterilizing Water by Ozone.**—That ozone is a powerful destroyer of organic matter, be it vegetable or animal, is as well known as the fact that most drinking waters need sterilization. The question, therefore, is not whether water can be sterilized with ozone, but it is to show that it can really be

carried out effectively at a cost which is not prohibitive; it is, therefore, a question which can be decided only in actual practice on a large scale. If ozone could be generated at anything approaching the theoretical efficiency, the problem would probably be a comparatively easy one, but even the best ozone generators are horribly inefficient, as they generate only a few per cent. of the amount of ozone which corresponds to the energy consumed. There are other practical difficulties, such as getting the gaseous ozone in contact with each of the particles of such enormous quantities of water as are used in a city. Many systems have been proposed and some have been tried, but few have survived. The Vosmaer-Lebret system, however, seems to have stood a fair trial, as it has been used commercially in Schiedam and later in Nieuwersluis, near Amsterdam. In the former city it was used for eleven hours per day during two periods of six months, without any interruption, which speaks well for it. A description of this process was recently given in a Bunsen Society paper by H. J. VAN'T HOFF, which is reprinted in the *Zeit. f. Elektrochemie*,



July 24th. Briefly described, there is an alternator generating current at 110 volts and 100 periods, which is raised to 10,000 volts by transformers, and is used directly at this voltage to generate ozone. The apparatus itself consists of a large number of metal tubes, in each of which the ozone is formed by means of the so-called dark discharge, there being a special device (not described) which prevents any other and undesirable forms of discharge, such as sparks or arcs, and it thus becomes possible to work without any solid dielectric, which is a great advantage in practice, as glass would be the only dielectric to use, and this is apt to break. The air is first dried by means of chloride of calcium, and is then passed through the apparatus at the rate of 40 liters per minute or even faster. No cooling is resorted to and a concentration of 3.5 to 5 milligrams per liter is obtained, depending upon the speed of the air; from 3 to 3.5 has been found sufficient for sterilization purposes. This ozonized air is then pumped into the sterilizer, entering at the bottom and leaving at the top, as shown in the adjoining illustration, the coarse impurities in







conductivity of monovalent ions. He seems to have found the interesting fact that the temperature coefficient is simply a function of the mobility, whatever be the chemical nature of the ion. Referring to the adjoining figure, the mobilities at  $18^\circ$  are shown as abscissas and the corresponding temperature coefficients as ordinates, and it will be seen from this that the monovalent ions Li, Na, F, Ag, K, Cl, Tl, I, Br, Rb, Cs, are all on the same curve, while ions of other valencies are not. Moreover, he found that the mobilities of the positive and the negative ions tend to become equal at rising temperatures. In attempting to frame a theory of this curious disappearance of the intrinsic differences of the ions, he conceives the ions as being surrounded with a film of water, whose thickness varies with the nature of the ion and reduces the mobility to a function of the friction of water against water, thus forming a third element which governs the two quantities, which he has shown to be dependent on each other. In the other paper above referred to, by HITTORF, the author shows his true scientific spirit by calling attention to, and correcting, a mistake in his determinations of transport numbers which he made about forty-five years ago. When clay diaphragms are used, there is no change of composition of the solution as it passes through the diaphragm, and in such cases there is no error in the transport numbers due to the diaphragm through which endosmosis always takes place; but when such diaphragms are made of animal membranes the action is different, at least for most aqueous solutions, as changes occur in the anode and cathode compartments which are not due to the electrolytic transference of the ions, even when the concentration is the same at the start, and, therefore, a determination of the transport numbers from the observed concentration changes may give wrong results. This is described in a Bunsen Society paper, in the discussion of which Le Blanc suggested that a diaphragm might be considered as a new kind of a solvent, in which the mobilities of the ions are different from what they would be in pure water, but the author did not seem to accept this hypothesis. The paper is reprinted in the *Zeit. f. Elektrochemie*, July 24th.

There is another paper on the theory of electrolysis, which was begun in the *Elek. Zeit.*, June, by PLATNER. It is a mathematical article on the electromagnetic theory of Maxwell and its application to the phenomena in electrolysis.

**Faraday's Law.**—It is a fortunate thing for electrochemists that Faraday's law, like Ohm's law, has so far withstood all attempts to show that it is incorrect, but, again like with Ohm's law, its application should be limited, or, in other words, it should be applied only to cases in which no other elements enter which are not really included in the law itself. Ohm's law, for instance, does not apply directly when counter e. m. f. or reactances exist in the circuit; there are similar cases in the application of Faraday's law. In a recent paper by BOSE, abstracted in the *Lond. Elec.*, June 13th, he discusses the range of validity of Faraday's law, calling attention to disturbing factors. For instance, the cation may be capable of existing with two different valencies, and in such cases it might be claimed that the law does not apply; such a case, for instance, is the one in which one bivalent ion reacts with one atom giving two monovalent ions. In another case, to which he calls attention, the apparent discrepancy is due to secondary reactions, as, for instance in the deviations found in the electrolysis of silver salts, such as in the silver voltameter, which amount to 0.0001 of the total weight of the silver deposited; among the important secondary reactions is the occlusion of oxygen by the platinum electrode. It might be said that such cases are somewhat analogous to an unknown leakage in an electric circuit, in which Ohm's law could no longer be applied directly; such errors, however, are due to an incorrect application of the law and not to an incorrectness of the law itself. He regards Faraday's law as an absolutely exact law of nature, and believes that there is absolutely no evidence of any metallic conduction in electrolytes, the whole

current being conducted by the transportation of materials. He compares Faraday's law with Dalton's law of multiple proportions, as far as exactness is concerned, and considers it an extension of Dalton's atomic laws.

**Heat of Combination.**—The probable source or origin of the heat of chemical combination is a fruitful source of speculation, and while probably of no great importance is, however, of considerable interest. T. W. RICHARDS, in a recent paper, calls attention to the fact that in many cases the contractions which are found to take place during different chemical combinations, are approximately proportional to the heat evolved, and he, therefore, believes that the whole source of chemical combination is the work performed in compressing the material; he carries this still further back and attempts to explain the origin of the heat of absorption, change of allotropic form and adhesion, which leads him to a hypothesis of the compressibility of atoms, which is discussed in detail. The paper is to be found in the *Proc. Am. Acad.*, Vol. 37, page 399, or in the *Zeit. Phys. Chem.*, Vol. 40, page 897, and is abstracted briefly in the *Am. Jour. Sc.* for July.

**Atomic Weights.**—While the question of atomic weights is a purely chemical one, yet the actual values are of such importance to electrochemists that laws concerning their relations are of interest here. Numerous papers have been written showing curious relations between atomic weights, intending to lead to some law existing between them, but most, if not all, of these fail to apply to some of the other elements. VINCENT, in a recent paper in the *Phil. Mag.*, for July, abstracted in the *Lond. Elec.*, July 11th, brings out a new numerical relation of this kind. He shows that the atomic weights are a certain power, namely, the 1.21 of a specific number for each element, which numbers are an ascending series and are always whole numbers, hydrogen being, of course, 1. This series shows certain gaps which he believes belong to elements which are yet to be discovered. A question, of course, is which serial number should be assigned to the element; iodine, for instance, shows the largest error, as the atomic weight thus calculated is incorrect by about 3.9 units, and to make this error fit his theory, he suggests that perhaps the wrong serial number was given to it; as these are all whole numbers, however, it would seem that there ought to be no difficulty in either finding the proper serial number, if the theory is correct, or if this cannot be found, then so much the worse for the theory. By changing its place with tellurium, the results would correspond better with his law.

**Gaseous Electrolytes.**—Gases are found to have a property of being able to dissolve and ionize salts according to experiments made by HAGENBACH, described in the *Ann. d. Phys.*, No. 7, an abstract of which appears in the *Lond. Elec.*, July 4th. In his experiments he made a cell with platinum and copper electrodes, the solution being rubidium iodide in liquid sulphurous anhydride; rubidium iodide was chosen because it dissolved easily and had good conductivity. The resistance of the cell at  $157^\circ \text{C.}$ , which is above the critical temperature, was 500,000 ohms, but the e. m. f. was not sensibly affected by this rise of temperature; it was 0.12 volt at  $100^\circ$  and 0.07 at  $26^\circ$ , while at the above-mentioned temperature it was 0.1. Iodide of copper was formed by the oxidation of the copper electrodes. He explains the low conductivity of gaseous electrodes by stating that while the gas is capable of ionizing a salt in solution, yet there are so many more chances for the re-combination in a gas than in a liquid that the number of free ions is kept very small.

**Sulphur.**—Among the other experimental researches described during the past month, is an article of some interest by RIEDER, published in the *Zeit. f. Elektrochemie*, June 5th. He found that a compound of copper and sulphur was formed electrolytically, or, at least, during an electrolytic process, under certain conditions. The cathode in the copper plating bath was made in the form of a bar surrounded by a non-conducting cylinder of sulphur, but the bar was also exposed to the elec-

trolyte above this ring of sulphur, and after about twenty hours the sulphur cylinder had become blue-black over its surface where it was in contact with the copper, while the latter had been eaten away somewhat at the same point. He believes that this compound acts like an electrolyte and that its formation continues deeper into the sulphur; if the latter is made conducting by the admixture of a powdered conductor, this compound forms all over the surface at once. He also tried using this compound as one plate of a battery, the other of which was zinc and the electrolyte ammonium chloride mixed with zinc chloride; when giving current, hydrosulphurous acid is formed, which in turn forms zinc sulphide; he does not, however, make any great claims for this combination as a useful battery.—Another experimental research in which sulphur plays a part, was described, by KUESTER in a Bunsen Society paper, abstracted in the same journal July 24th. In electrolyzing polysulphide solutions, he noticed that the measuring instruments showed periodic variations, and upon investigation he found that they were due to a layer of sulphur on the anode, which was periodically formed and destroyed, acting like an insulator while it was there. He is still seeking for an explanation of the cause, but gives some preliminary results for the potential difference between platinum and silver electrodes and different concentrations of different chlorides saturated with sulphur.

**Bromine.**—KELLNER, several years ago, found that pure, dry chlorine gas had properties which ordinary chlorine has not, when high-tension currents are sent through it. In a recent Bunsen Society paper, published in the *Zeit. f. Elektrochemie*, July 24th, he describes experiments made with carefully-purified bromine in vessels of glass free from lead, and found that after some days yellow crystals had been deposited on the walls of the vessel, which he is sure do not come from the glass, but he does not know what they are. Some of those who discussed the paper concluded that it was a compound of bromine with the glass, while Ostwald suggested that it might be a case of isomerism.

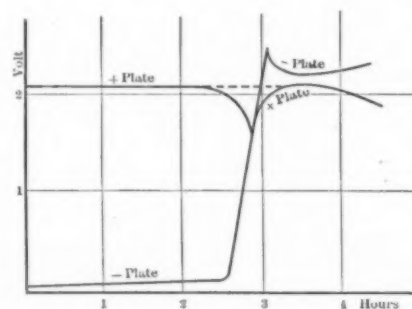
**Alternating Current Electrolysis.**—This subject has been the basis of much research but as yet without much practical value, though nevertheless of interest. One of the ruling factors seems to be the current density, and we presume that the frequency of the alternations also has a considerable effect on the result, for it is not unreasonable to suppose that when the electrolytic process is not reversible a compound will be formed if the current continues in one direction long enough to overcome what polarization there may have been, and if the process is not reversible this compound will not change on the reversal of the current. TROTTER recently made some experiments with alternating currents between lead plates, from which he concludes that such currents will electrolyze lead pipes if the current densities are lower than 1 ampère per square inch, which is an extremely high-current density, but the amount of the electrolysis, he claims, should be determined by those who advocate electric traction by alternating currents as a solution of the problem of destruction by return earth currents; but unfortunately those are the very ones who would prefer to assume that the amount was zero. The experiments are described in the *Lond. Elec.*, July 11th. He used lead pipes a few inches apart, separated by moist earth; the frequency was 83, the voltage 100 and the dampness was adjusted to maintain 1 ampère, which does not convey any idea as to the actual amount of dampness. He thus found that after six weeks there was a well-defined incrustation on the lead, confined to certain parts of the pipe. He repeated these experiments for other current densities. The nature of the earth used is also somewhat indefinitely described, as he stated he took it from his garden in front of the office.

**Chlorides.**—MUELLER, in the *Zeit. f. Elektrochemie*, July 3d, gives an illustrated account of experiments in which he investigated the electromotive behavior of hypochlorous acid and chloric acid, in which he found a great difference when

he used plain platinum anodes and when he platinized them, obtaining much better results in the latter case.

#### PRIMARY AND SECONDARY BATTERIES.

**Lead Batteries.**—Several articles have been published recently on the lead accumulator, some of which are of interest as showing that although this is a well-threshed-out subject, there are still matters of interest cropping out. Frequently the plates of an accumulator are simply connected together regardless of their individual capacities, and then as a rule the useful capacity of the whole accumulator depends largely upon the weakest plates, especially with high discharges. It is therefore of interest to be able to determine the behavior of individual plates, or groups of plates, during a discharge, as in a well-constructed accumulator, where lightness is an important consideration, it is very desirable to have all the plates of exactly the same capacity and the end plates of half the capacity of the others. This may be done by means of an auxiliary electrode which serves to measure the potential difference between that electrode which is assumed to be standard and the plate to be tested. A method known as Fuch's method was recently applied by LIEBENOW, whose name is well known in connection with accumulator researches, and is described by him in a recent Bunsen Society paper which has not yet been published in full, but is abstracted in the *Elek. Zeit.*, June 12th. He applied it to a battery with two



DISCHARGE CURVES.

plates, or sets of plates, and claims that the method is very useful in repairing batteries that have lost their capacity. He describes three different forms of auxiliary electrode. The first consists of a cadmium plate in an ebonite frame, and is sufficiently good for rough determinations; care should, however, be taken that when the plate has been used the sulphuric acid should not be left to dry on it, as cadmium sulphate would be formed, which would cause errors in the next test. Zinc instead of cadmium is not suitable because zinc dissolves much more rapidly in sulphuric acid than cadmium. For more exact measurements LIEBENOW uses solid cadmium amalgam, which is suspended in a small bottle of "Pukall" material (a material much used in Europe for porous diaphragms) and is surrounded by a solution of cadmium sulphate and sulphuric acid; such an electrode is very constant. It is placed over the plates in the accumulator. During the discharge of the e. m. f. between this auxiliary electrode and the two battery electrodes is measured and the curves are plotted with the e. m. f.'s as ordinates and the times as abscissas. A sharp bend in a curve shows that the capacity of the plate is exhausted. For very exact measurements a small, carefully-treated accumulator plate is suitable; as an auxiliary for testing the negative plate a small, spongy, lead plate is used, and for testing the positive plate a peroxide plate may be used, as very sensitive voltmeters can then be used on account of the smallness of the e. m. f.'s. There are cases in which both curves show sharp bends, although only one plate is exhausted. The adjoining diagram has been plotted from tests of a

storage battery the negative electrode of which had a smaller capacity than the positive one. At the beginning of the discharge the negative plate has an e. m. f. of 0.1 volt against cadmium; this e. m. f. increases slowly until the plate has been converted into sulphate; after two and one-half hours the e. m. f. increases rapidly to about 2.5 to 2.6 volts, when the "discharge" is continued by force, by continuing to send a current through the cell; the negative plate then becomes peroxidized. The curve has a sharp maximum when a strong development of oxygen occurs; it then drops, the development of oxygen stops, and the curve takes the shape of the normal one of the peroxide plate. On the other hand, the positive plate has, at the beginning of the discharge, an e. m. f. of 2.1 volts against cadmium, and the curve drops definitely when the plate is discharged; this normal behavior is represented first by the full line, then by the dotted line and finally by the full line. In certain cases, however, the curve drops before the capacity of the plate is really exhausted; in such cases it occurs at the same time when the curve of the other plate shows a sharp bent; but the curve of the positive plate rises again after it has met the other curve (i. e., from the point where the e. m. f. of the battery is zero); it drops later again definitely when the plate is really exhausted. This behavior is represented in the adjoining diagram by the full line throughout. It looks as if the curves for the two plates influence each other. In such cases the Fuch's method gives wrong results, as it seems to indicate that the positive plate is exhausted at the front bent of its curve, which is not really the case. Only by continuing the experiment, as is done in the adjoining diagram, the real condition would become evident, but it is, of course, impossible in practice to do this. He explains this peculiar phenomenon as follows: If at the ends of a battery there are plates of the same capacity as the plates in the center, then the end plates are not yet exhausted when the plates in the center are; the lines of current then no longer go from plate to plate, but around the sides of the plates in the center, that is, there are "stray" currents; the same is the case when the contacts of a plate are bad and when it is not discharged uniformly with the other plates; such stray currents cause wrong measurements.

Although the Faure type of accumulator was considered at the time of its first invention to be a very great improvement over the older Planté type, yet experience covering many years has shown that this view was premature, as for the positive plates at least, many makers, have gone back to the Planté type. The objection to this is, of course, the cost of formation. While it may almost be assumed that most chemicals had already been tried for hastening this formation, yet PETERS, with the proverbial patience of a German, has, it seems, spent an enormous amount of time and patience making an almost endless number of experiments with a very large number of chemicals, and with the thoroughness of his countrymen he seems to have made these experiments systematically and intelligently, and gives the results so that they have a real value. For a long time past he has been publishing the results in the *Centralbl. f. Accum.*, and while they have not yet been completed, they are of considerable value as they indicate that quite a number of materials will give fairly good results, while others give practically nothing. It would be impossible to give all the results here, and readers are referred to that excellent journal for the figures; a few of them, however, published in the numbers of April 1, May 1, and June 1, may be repeated here. Theoretically, 100 ampère hours could form 222 grams of peroxide of lead; the results given below were obtained with a current of 0.6 ampère and a surface of 144 sq. cm. About 35 grams of peroxide were obtained from 900 c. c. of a 15 per cent. solution of magnesium sulphate mixed with a solution of 30 grams of ammonium sulphate and 20 grams of crystallized hydroxide in 100 c. c. of water; 3.5 were formed in 30 grams of crystallized magnesium sulphate and 20 grams of sodium sulphate free from water added to 1

liter of water, the specific gravity of the solution being 1.026; about 1.16 grams, in a solution of 30 grams of bichromate of potassium and 12 c. c. concentrated sulphuric acid in 1 liter of water. The other results given in those parts are below these, but in other portions of his series of articles he gives results far superior to those given in these later parts. It may be assumed that after working as hard as he has he will not publish to the world the best results, and in this connection a small advertisement in that journal is of interest, as it states that a process for the formation is for sale, but does not state that it is his process.

The same journal of June 15, contains an account of a long series of tests made of French storage batteries to be used in the French navy. They were all discharged together in series, the discharge being stopped when the e. m. f. had fallen to 1.65 volts, and when this happened in less than half an hour the cell was not considered. After 251 discharges there were still five batteries left, four of which had pasted plates throughout, while the fifth had formed positive plates and negative pasted plates. There were altogether at the start 21 batteries by 13 different makers, 11 of which had pasted plates throughout, nine had formed positives and pasted negatives, while in one both plates were formed.

WEHLIN and LANGSTEIN, in the *Centralbl. f. Accum.*, June 15th and July 1st, have an article on troubles with storage batteries, in which they discuss these and give various reasons for the gradual destruction of the plates.—At the recent DUSSELDORF EXHIBITION a number of storage batteries were exhibited, some of which are described in that same journal, May 15th and July 15th.

*Other Forms of Storage Batteries.*—The lead-zinc storage battery has tempted many inventors, and descriptions of it crop out periodically, but in every case, as far as we can recall, it again vanishes as a failure; it seems to survive only as a sort of temporary storage device for very short periods, such as when used as an equalizer for brief periods of fluctuations. We fear there is little hope of this type of cell coming into practical use, but its great capacity per pound still makes it a very tempting direction for possible improvement. GABRAN, in the *Elek. Zeit.*, June 26th, describes some experiments with such a battery, accompanied by diagrams and tables. The case is made of copper, amalgamated on the inside and divided into departments by means of perforated amalgamated sheets, all of which form the negative plate, while the positives are ordinary peroxide plates, the electrolyte being, as usual, zinc sulphate and sulphuric acid. The cover and all binding posts are made of aluminum, which we fear is not a wise departure. Discharging it from 2.4 to 2.1 volts during a period of ten hours, he obtained with one battery 331 watt-hours for 14.3 kg. of total weight, and with three others 50.6, 81 and 72 watt-hours, respectively, for 3 kg., 2.5 kg. and 2.5 kg. of electrodes alone. He experimented with them for a year and a half and finds no reason why they should not be used in practice; he claims that the copper is not attacked. While it may be true that the copper was not attacked in his cells, it is hardly likely that this would be true when the cells are used in practice, for if a single cell in a series should be overdischarged, the copper is sure to go after the zinc, which has been deposited on it during the charge, is all gone. There is another serious objection to this type of cell, which is not generally stated and perhaps not generally known. It is that the sulphuric acid is electrolyzed easier than the sulphate of zinc during the charge, which means that much of the charging current will be used to generate hydrogen on the cathodes, and this is especially the case when the contents of the zinc sulphate in the solution gets low towards the end of the charge. It is for this reason that it is almost impossible to get zinc out of a zinc sulphate solution when there is present a large amount of sulphuric acid; this wasted current will also evolve oxygen on the peroxide plates, as they will of necessity be fully charged long before the corresponding amount of zinc



has been deposited on the cathodes. We fear that this battery is a theoretically hopeless case, unless some solvent for zinc can be found which is equally effective in generating a high e. m. f., and which will decompose at a higher voltage than the zinc solution.

The *Centralbl. f. Accum.*, July 15th, contains an abstract of a patent of GAHL, who proposes to make porous silver oxide electrodes, like those used in the Jungner cell, in alkali storage batteries. He mixes fused-silver chloride with about 15 per cent. to 20 per cent. of lead chloride, and then removes the chlorine by using the plate as a cathode in an alkaline-hydrate solution; then removing the lead by using the plate as an anode in another solution, which is not given, the silver being at the same time oxydized.

**Standard Cells.**—The very exhaustive series of tests of the Clark and the Weston cells, conducted more especially at the Reichsanstalt, have greatly increased the confidence which one can now have in their constancy and reliability. In fact, they are now, together with the standard resistances, the real basis of exact electrical measurements; they can now be made to be exact and uniform to within 0.01 per cent. and will remain constant within this limit. Among the recent papers on such cells is another emanating indirectly from the Reichsanstalt, by JAEGER, who has devoted much time at that institution to a study of these cells; it is a Bunsen Society paper, published in the *Zeit. f. Elektrochemie*, July 24th, and abstracted in the *Centralbl. f. Accum.*, July 15th. He first discusses at some length the Clark cell with saturated electrolyte, and an excess of solid zinc sulphate, several forms of which he describes and illustrates. At 15° C. the generally accepted mean value of the e. m. f. is 1.433 volts, which is in exact agreement with Carhart and Guthe's determination. The formula accepted by the Reichsanstalt for the e. m. f.  $E$ , in international volts at the temperature  $t$  degrees C., is  $E = 1.4328 - 0.00119(t - 15) - 0.000007(t - 15)^2$ . He briefly discusses the changes taking place in the Clark cell at a temperature of 30°, which are interesting from a physicochemical point of view. As the high temperature coefficient of the e. m. f., which is about 0.08 per cent. per degree, necessitates a troublesome correction, Weston and Carhart have proposed using a dilute zinc sulphate solution; for instance, saturated at 0° C., is the temperature coefficient is thereby diminished to one-half, but such cells have not been defined with sufficient precision. He then mentions briefly the Helmholtz calomel cell, consisting of zinc, zinc chloride, calomel and mercury, but it is not suitable as a standard cell, because different cells do not give uniform values; the calomel does not seem to be a sufficiently good depolarizer. The Weston cadmium cell is an excellent standard cell and has a very small temperature coefficient; he believes that in course of time it will entirely replace the Clark cell. The Weston Co. use a dilute solution of cadmium sulphate, saturated at 4°, while the measurements made in the Reichsanstalt were nearly always made with a saturated solution, with an excess of solid crystals. For a cell with dilute solution the temperature coefficient is practically equal to zero within the ordinary temperatures; the e. m. f. is 1.0191 international volts. The e. m. f.  $E$ , in international volts of the cell with saturated solution and crystals, is given by the formula  $E = 1.0186 - 0.000038(t - 20) - 0.00000065(t - 20)^2$ . At 4° C. both types of cells have nearly the same e. m. f.; neither shows a lagging of the e. m. f. behind the temperature, a fact which is self-evident for cells without crystals; there is no cracking of the vessel at the negative pole on account of the amalgamation of the platinum wire and there is no development of hydrogen. The cadmium amalgam must have between 5 and 14 per cent. of cadmium. Contrary to some experiments by others, the very numerous measurements of the Reichsanstalt have not shown any irregular behavior whatever of the Weston cells at 15°, provided a cadmium amalgam below 14 per cent. was used. From measurements extending over several years, the following values of the ratio of the e. m. f's.

of the Clark and the Weston cell were found: Clark at 0° to Weston at 20° 1.42280; Clark at 15° to Weston at 20° 1.40669. These ratios have not changed by more than 0.0001 in four years. A standard cell must represent a reversible chemical system and would theoretically have the best form, if the electrolyte is also present in solid form. The depolarizer is best when solid and a good conductor. When mercurous sulphate is used, there are complications due to its solubility.

There was another article, also a Bunsen Society paper, in the *Zeit. f. Elektrochemie*, July 24th, by LUTHER, in which he discusses the question of the degree of chemical purity of the electrolyte in order to obtain the required exactness. He considers a Clark cell with saturated zinc sulphate solutions and zinc sulphate crystals, and investigates, by a thermodynamical several years, the following values of the ratio of the e. m. f's. be when the zinc sulphate solution contains an addition, say, of glycerine. He imagines two Clark cells connected against each other; that is, positive connected with positive, the electrolyte of the one being pure and that of the other containing glycerine. This system is imagined to first give out current and then to be brought back again to its initial condition by means of isothermic distillation. From the laws of thermodynamics, it then follows that the e. m. f. of this system, namely, the difference between the e. m. f's. of the two cells, depends only upon the ratio of the vapor pressures of water of the electrolytes of the two cells, a conclusion which he then confirmed experimentally. One Clark cell contained an impurity of 50 per cent. by volume of glycerine, while the electrolyte in the other was pure; the difference of the e. m. f's. of the two cells was found to be 0.00744 volt at 25°, from which he obtains, by means of his theory, the ratio 1 to 1.09 for the vapor pressures, while it was found experimentally to be 1 to 1.10, thus confirming his theory. He draws the following interesting conclusions from his theory: if the solid crystals in a standard cell with saturated solution (corresponding to the zinc sulphate crystals in a Clark cell with saturated zinc sulphate solution) are free from water of crystallization, then the e. m. f. must be independent of impurities and of the solvent. He is trying to devise a practical standard cell in which this condition is fulfilled.

#### GENERAL AND MISCELLANEOUS.

**Silver Voltameter.**—The sources of error in the silver voltameter were the subject of careful research by the Reichsanstalt some years ago, and it was then shown that for precise measurements very great care must be taken, as the sources of errors are quite serious, so much so that it really becomes quite difficult to use it, and the standard cell, combined with the standard ohm, therefore gives a more reliable ampère. LEBUC has recently presented a paper to the French Academy, published in *Comptes Rendus*, July 7th; *L'Eclair. Elec.*, July 26th; *L'Ind. Elec.*, July 25th, and *Lond. Elec.*, August 1st, in which he discusses some of these sources of error. One lies in the change produced in the acidity or alkalinity of the solution, some observers claiming that it becomes acid, while others say it becomes alkaline; this, he shows, is entirely a question of circumstances, such as the rapidity of the electrolysis. The nitric acid which is generated is electrolyzed at the same time as the nitrate of silver itself, but no hydrogen is evolved, as it precipitates silver from the nitrate and also forms a complex compound with nitrogen and hydrogen. There is popular misapprehension that the deposit of silver on the cathode is corroded by the solution, but he shows, by careful weighings, that such a corrosion does not exist. On the other hand, there must be an appreciable polarization of the cell, which is usually supposed to be negligible; he estimates it to be 0.03 volts. He mentions the fact that if a silver plate is put into the cell, but not connected to the circuit, it shows a slight loss of mass, whereas there is no such loss when a silver needle is used instead; the loss in the case of the plate depends upon the way in which it is immersed, being greater when it crosses the current.



## CORRESPONDENCE.

## THE PROSPECTS OF THE ELECTROCHEMICAL INDUSTRIES.

To the Editor of the *Electrochemical Industry*:

SIR:—The year 1902 will mark an epoch in the development of practical electrochemistry in the United States. Heretofore, patient experiment, close thinking and hard work on the part of individuals have resulted in the commercial success of certain electrochemical establishments. All that has been done has been the result of unorganized effort and American "get-there-ness." There have been some bad wrecks and on the shore are seen the hulks of once fair craft, stranded because of the lack of knowledge of previous failures. For "by our failures do we learn rather than by our successes."

At the present day, we see several of our universities and technical institutions offering courses designed to furnish their students special knowledge of electrochemistry. We also see the founding of a society which brings the practical men and the theoretical men together, and where also an enlightened self-interest has caused frank discussions of practical problems to be in order.

Finally, we witness the start of a technical journal with good auspices, which journal will chronicle the progress of this new applied science in its vigorous youth—at the same time helping the growth to be normal, yet rapid.

That such a field now exists is to my mind shown clearly by the low rates that hydraulically-generated power can be bought at the present time. Such inducements are offered for electrochemical works to locate, and the terms are so attractive, that one is forced to the conclusion that these large plants wish to expand and to sell power in large amounts at a small profit. The potential supply certainly exceeds the possible demand.

In any electrochemical process, be it electrolytic, electrothermal or a combination of the two ways, the cost of power is a large fraction, often 25 to 90 per cent. of the entire cost. The old electrochemical theory of Berzelius is so modified that we know that variations in chemical potential are strictly proportional to variations in electrochemical potential. For example, lead is easier reduced than zinc, zinc than magnesium, magnesium than sodium. In their electrolytic potential these metals stand in the same relative positions. Similar facts can be cited in regard to the non-metals, *e. g.*, fluorine, chlorine, bromine and iodine.

Accordingly, it can be assumed that any metal can be reduced or any compound formed by using the correct electrolytic potential. This is not strictly true, but only an approximation, because uniform conditions cannot be maintained. But by studying the conditions of temperature, current, electrolyte, etc., it may be said that the majority of chemical products can be produced by electrochemical means. The electric furnace has also put at the disposal of the chemist and metallurgist such temperatures that a new chemistry has been founded. "Electrochemistry" is the easiest means of regulating thermal potential.

Cheap power is, of course, the fulcrum that will enable the electrochemical Archimedes to carry to commercial success the manufacture of chemicals. Freight, labor, cheapness of materials, convenience to markets, such questions will be all settled as the great power plants become more and more industrial centers. The United States has in these plants greater possibilities for development than any other country, because they are near at hand to our water-ways and not too far distant from present centers. The falls of Niagara are commercially in touch with New York. The falls of Zambesi are commercially remote from London. The law of inverse squares holds here in business as in gravitation.

The utilization of this power is the "electrochemical industry." The journal bearing that name must co-ordinate incoherent ideas, simplify practice, extend our knowledge of the

pure science. We wish, not to drink deeply, but to run a pipe line from the Pierian spring of theoretical electrochemistry, to the tidewater of practical achievement. The experience of the sponsors of the *ELECTROCHEMICAL INDUSTRY* in other lines, lead us to believe that it will fill the known want.

WOOLSEY MCA. JOHNSON.

New Brighton, N. Y.

## BOOK REVIEWS.

ELEMENTARY PRINCIPLES IN STATISTICAL MECHANICS DEVELOPED WITH SPECIAL REFERENCE TO THE RATIONAL FOUNDATION OF THERMODYNAMICS By J. Willard Gibbs. New York: Chas. Scribner's Sons, 1902. 207 pages. Price, \$4.00.

This is one of the volumes of the "Yale Bi-centennial Publications," issued in connection with the bi-centennial anniversary of Yale University, "as a partial indication of the studies in which the University teachers are engaged," and Old Yale may be proud of J. Willard Gibbs.

Prof. Gibbs' studies in thermodynamics and in the application of thermodynamical methods to problems of physical chemistry, were begun many years ago. The work that Gibbs has done in this line in his younger years, was ahead of that time and, moreover, was of such a highly theoretical and analytical nature that it appealed to only very few, and was soon forgotten, until in the last ten or fifteen years the rapid and enormous development of physical chemistry in general and especially of electrochemistry set in. Attention was then directed to Gibbs' early work, especially by German scientists. Planck, in starting his valuable thermodynamical investigations, followed closely the footsteps of Gibbs, and Ostwald translated the early important papers of Gibbs into German. It soon became apparent that many interesting results obtained independently by new investigators had been anticipated many years ago by Gibbs. Since then Gibbs' name has become more popular, and as an indication that he is now well known even in his own country, we may recall the hearty applause that followed a few well-chosen words spoken in his honor by Prof. Carhart in a discussion of a paper at the inaugural Philadelphia meeting of the American Electrochemical Society.

This latest book of Prof. Gibbs is of the same highly theoretical nature as his former work. To all but the advanced student it is very difficult reading, as it requires a thorough knowledge of the higher mathematics and of mathematical physics. "Statistical" mechanics (the name is due to Maxwell) is a branch of mathematics which owes its origin to the desire to explain the laws of thermodynamics on mechanical principles, and of which Clausius, Maxwell and Boltzmann are the principal founders. Prof. Gibbs, in his present book, deals with statistical mechanics as an independent science, but while he does so, he always gives an outlook into thermodynamics, and puts old thermodynamical principles into a new light.

While the work is of the highest value from a scientific point of view, and will be appreciated by the advanced student, it can hardly be said to appeal to the industrial electrochemist. It cannot be questioned that the theory of electrochemistry of the future will be founded on the principles of thermodynamics. But to make such a theory popular and the common property of electrochemists and electrochemical engineers, it will first be necessary to find a rational foundation of thermodynamics itself. From his point of view, Prof. Gibbs is undoubtedly right in attempting to find such a foundation in statistical mechanics; but others look at this from a different standpoint. We are still far from having standardized thermodynamical terms and methods; to mention only one example we may quote James Swinburne's recent attempt to attack the problem from the electrical point of view; he is primarily an electrical engineer, so he tries to develop the principles of thermodynamics in a way strictly analogous to

the theory of electricity. From the point of view of an electrical engineer this is a "rational" starting point, but whether it will lead to a complete and correct demonstration of thermodynamics, it is for the future to show.

Prof. Gibbs' book is divided into 15 chapters. In the first he gives the general ideas and discusses the "principle of conservation of extension-in-phase." In the second and third chapters he applies this principle to the theory of errors and to the integration of the differential equations of motion. In the fourth and following chapters he considers statistical equilibrium and conservative systems. He treats especially of what he calls the "canonical" distribution, in which the index of probability is a linear function of the energy. While in other chapters he often touches briefly on thermodynamical analogies, the fourteenth chapter is devoted entirely to this. In the last chapter he deals with systems composed of molecules; he introduces this supposition at the end of the book, because he wants to separate very decidedly the purely thermodynamical laws from those special modifications which belong rather to the property of matter.

TRANSACTIONS OF THE AMERICAN ELECTROCHEMICAL SOCIETY. Vol. I. Philadelphia: Inaugural Meeting, 1902. Published by the Society in Philadelphia. Price, \$3.00 in cloth; to colleges, libraries, societies and journals, \$2.00; to members, free. 250 pages; illustrated.

This is the first volume of the transactions of this new national society, which was formed in Philadelphia last April at the suggestion of a few electrochemists in Philadelphia, who had been meeting informally for several years to discuss electrochemical subjects. A preliminary meeting of the more prominent electrochemists in this country was called in Philadelphia last November to discuss the question of founding such a society, and it was decided that if 75 members could be secured the society should be founded and a formal meeting arranged for. While some of those who attended the preliminary meeting, and a number of those who sent their opinions in writing, had grave doubts about the advisability of starting such a society, the majority were of a different opinion. The fact that in a short time about 350 members were secured, showed that the time was ripe for the formation of such a society.

The present volume consists chiefly of the 20 papers that were read at the first formal meeting. These are published in full and are followed by the revised stenographic report of the discussions, which latter are in a number of cases extremely interesting. A number of these papers are illustrated, some of them with half-tone inserts. It would require much space to give even a brief review here of the papers themselves; it suffices to say here that they included a wide range of subjects on industrial, theoretical and experimental work or subjects, and on instruction in electrochemistry, many of them are of considerable interest. With perhaps one unimportant exception, these papers are all new and original matter. The intention seems to be to publish a volume after each meeting, the number of meetings depending upon the number of papers which can be secured, and other considerations.

A somewhat peculiar and striking color has been chosen for the cover of these *Transactions*, evidently for the purpose of attracting attention, as we do not remember having seen any book or journal with a cover of the same color.

Besides the papers this volume contains a portrait of the first president, Joseph W. Richards, some introductory remarks by the president, a historical sketch of the formation of the society, the proceedings of the business meetings, the constitution, and the catalogue of the members; those in the present list have the honor of being called charter members. The general make-up of the book is about like that of the transactions of other national societies and is very creditable to such a young society. These transactions promise to become important in the literature on electrochemistry.

### REGULATING RHEOSTATS.

While rheostats are a necessary accessory in nearly all the different branches of electrical engineering, they are of special interest to electrochemical engineers for two reasons: first, because successful operation of electrochemical processes generally requires that the voltage and the current necessary for a special purpose are maintained with great exactness during the operation; second, because the use of relatively very high cur-

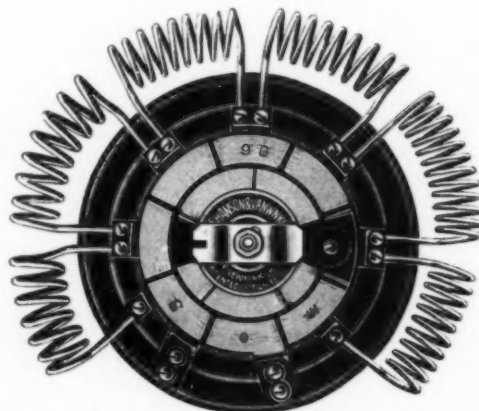


FIG. 1.—DYNAMO RHEOSTAT.

rents for electrochemical processes has made a special design of rheostats indispensable for such purposes.

For instance, any electroplater knows that different voltages are required to operate successfully different kinds of solutions. If the correct conditions are not maintained during the process of electroplating, the results are unsatisfactory; if the current becomes too great (i. e., if the e. m. f. applied at the

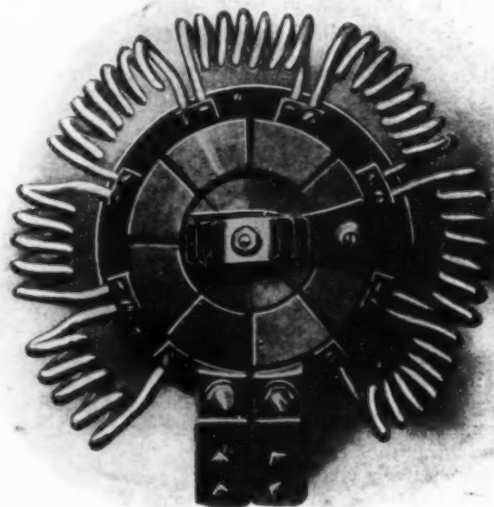


FIG. 2.—RHEOSTAT FOR ELECTROCHEMICAL PROCESSES.

terminals of a given electroplating tank is greater than required) there is a tendency to burn and blacken the work to a marked degree.

The accompanying illustrations represent three rheostats made by the Hanson & Van Winkle Co., of Newark, N. J. The rheostat shown in Fig. 1 is made to carry from 10 to 250

amp. and is used for various purposes, especially in connection with dynamos; in the smaller sizes for field regulation and in the larger sizes for carrying the main current.

Figs. 2 and 3 show rheostats for use in electrochemical processes and especially in electroplating. The rheostat, Fig. 2, carries currents from 800 to 1,000 amp. without excessive heating; the duplex rheostat, Fig. 3, carries currents of 2,000 amp. It has sufficient wire to allow of toning down the highest electromotive force used in electroplating. Enough segments are used to reduce the e. m. f. to two volts and at the same time avoiding any excessive heat and danger from fire. All the segments, lever arms and connections are made of a special copper casting, and their calculations are all based on a carrying capacity of 1,000 amp. per square inch. These are mounted on an iron base, which is insulated from the copper segments with a specially prepared vulcabeston insulating material, heat or moisture having no effect upon it. The rheostats are then mounted on marbleized slate and the whole is then mounted on a handsomely polished oak base board. As there is always a great deal of moisture and acid fumes in a plating room, the resistance coils are given a heavy deposit of zinc, which amply protects them from rusting. These coils are made from a special resistance wire, which

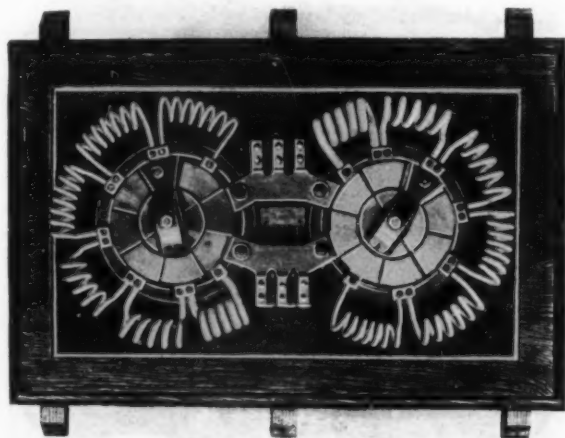


FIG. 3.—MULTIPLE RHEOSTAT.

is carefully tested for its resistance and carrying capacity, and graduated on each rheostat from a light to a heavy wire according to the current it has to carry, and at the same time giving sufficient reduction in voltage for a large or small amount of work.

The multiple rheostat, Fig. 3, has the advantage that one of the resistances can be thrown out of the circuit by moving the lever arm on the off segment. This can be done when a current of 1,000 ampères or less is being used. By this method four times the resistance is obtained. As the load is increased the other rheostat is thrown in the circuit. This size of rheostat is used in the main line to control the voltage of several large tanks, or very large galvanizing and acid copper solutions, also for special purposes where large currents are to be used.

The Hanson & Van Winkle Co. have for many years installed numerous successful plants for electroplating. Their stock of apparatus and accessories, required for cold galvanizing plants, is complete. They also carry in stock chemicals, polishing lathes, polishers' and buffers' supplies, grinding machinery, plating dynamos and lacquers.

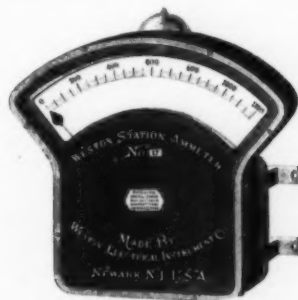
### EXTERNAL SHUNT AMMETER.

Special electric installations require special measuring instruments. The rapid and enormous development of high-tension power transmission in recent years has necessitated special devices and designs for instruments to be used at very high voltages. On the other hand, in electrochemical industries it is the current which is abnormally high; and, as for electrochemical processes, it is generally essential to keep the current strength under control. It is important to use ammeters, which enable an exact measurement of very large currents and which, at the same time, consume only a small amount of energy.

The accompanying illustration shows a Weston ammeter of the "external shunt" type, which involves a method of action quite different from that of the usual type of ammeter.

The difference of potential between two points on a conductor is directly proportional to the current passing through the conductor. If, therefore, the resistance between two points of a certain conductor is known and we want to measure the current which passes, a voltmeter connected at these points can be used to measure the current. Or if we know, in one case only, the potential difference which exists between the two points when a known current passes, then we can find in any case the current by measuring the potential difference. For example, if a voltmeter is connected to two points on a conductor, and it is known that with 1,000 amp. passing through the conductor the potential difference between these points is 0.01 volt, then a reading of 0.0155 volt on the voltmeter indicates that the current at that moment is 1,550 amp.

To make this method of measuring the current strength practical it is essential that the voltmeter used is sufficiently sensitive, so that a potential difference between the binding posts amounting to a small fraction of a volt will cause the pointer to move across the entire scale.



EXTERNAL SHUNT AMMETER.

It must be remembered that any drop of potential involves a loss of useful energy, and consequently there should not exist a great difference of potential between any points of a conductor on the same side of a translating device. The cross section of all conductors should be large enough to reduce this loss as much as is practical. The limit is reached when any increase in efficiency obtained by increased cross section of the conductor would be overbalanced by the increase of interest on the cost of the conductor.

The Weston shunt ammeter is, in fact, a voltmeter of high sensitiveness which gives a full scale deflection with 0.03 volt between its binding posts. In any plant such a small potential difference between points of the conductor will be found. In case the cross section of the conductor is based on one square inch copper per 1,000 amp., only a length of about  $4\frac{1}{2}$  feet would be required.

It will be seen that the conductors have not to be lengthened, bent or specially shaped in order to accommodate the ammeter, but that the instrument proper can be connected to two points of different potential by thin connecting wires. The maximum current flowing through the instrument never exceeds 0.06 ampères. Of course these connecting wires are an integral



part of the resistance of the instrument and, therefore, when once adjusted, must not be altered.

As the conductors in almost every electrical plant consist of copper, which changes its resistance considerably with change in temperature, it is often preferable not to use a part of the conductor as "shunt" for the instrument, but to insert a specially-made shunt of high resistance alloy having a small temperature co-efficient.

This has the further advantage that the combination of instrument and shunt can be properly adjusted in the laboratories of the manufacturer.

The expenditure for copper and labor required for installation is reduced by shunting the instrument, and a decrease in operating expenses is effected by the extreme sensibility of the Weston instruments. As already stated the Weston ammeter requires a potential difference of 0.03 volt between the binding posts and takes 0.06 amp. for full scale deflection. It consumes, therefore, not more than 0.0018 watt, whereas, most, if not all, ammeters of other types consume from 800 to 1,000 watts when measuring a current of 1,000 amp. Especially when powerful currents are used, these savings often exceed the total cost of the instrument.

The Weston Electrical Instrument Co., Waverly Park, N. J., manufacture these instruments in different styles of any required capacity, with and without illuminated scale, and also make voltmeters ranging from a fraction of one volt for full scale deflection up to 10,000 volts, and higher. Their line of portable testing instruments is complete and covers all special requirements met with in the different branches of electrical engineering.

#### ELECTRO-PLATING DYNAMOS.

Twenty-one years ago, in a building on Market street, Hartford, Conn., Arthur E. Eddy began the manufacture of dynamos for electroplating, and from that time the name "Eddy" has been accepted by users of this class of apparatus as guaranteeing the quality both with regard to con-

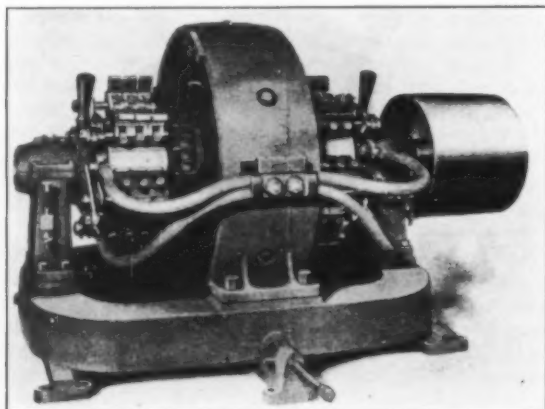


FIG. 1.—SIX-POLE ELECTROPLATING MACHINE.

struction and operation. As with all other forms of electrical machinery, the modern dynamo for electrolytic work is very different in design from the first ones, yet that they were good in every way is proved by the fact that several of the eleven first made are in commercial use to-day.

The maintenance of the enviable reputation of the "Eddy" machines is due to the fact that great care has been exercised in their design, the results of both theoretical and experimental researches being fully utilized.

The modern dynamo for electrolytic work must be simple, durable and efficient, maintaining its voltage, and running sparkless under change of load without the necessity of shift-

ing the brushes, and in the above particulars the "Eddy" machines are believed to be unsurpassed. Several years ago the use of the three-wire system in connection with machines of this class was found desirable, and double-commutator machines were designed. The saving in line loss and convenience of having two voltages available, more than com-

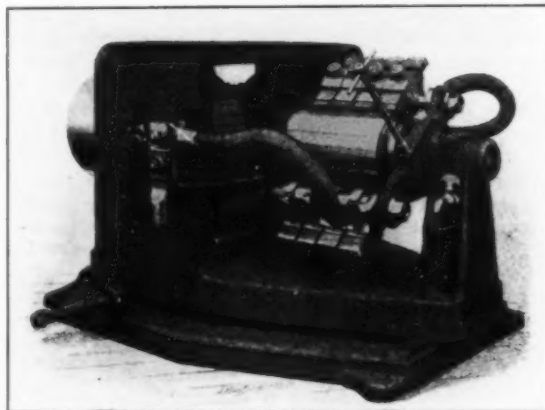


FIG. 2.—BIPOLAR ELECTROPLATING MACHINE.

pensates for the slightly increased initial cost. That low voltage, high-current machines without commutators could be made was also realized, and such a machine is in operation to-day, but the output in current and the necessary weight were so great that very little demand for them was to be expected. The accompanying illustrations show some of the machines as above described.

Fig. 1 shows the double-commutator, six-pole type, each

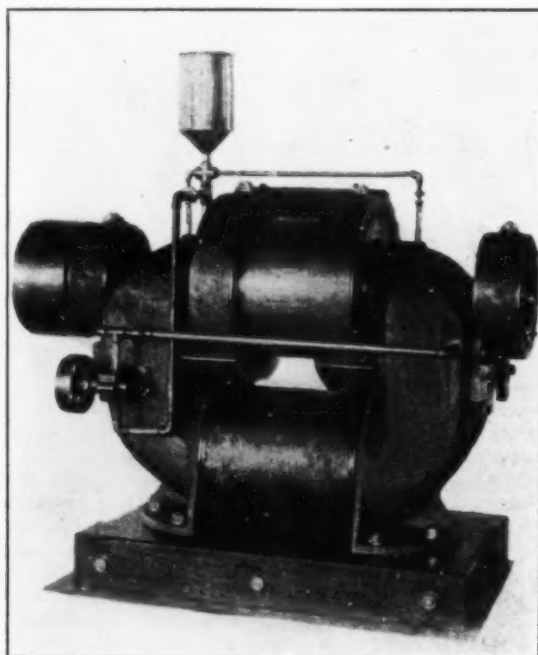


FIG. 3.—UNIPOLAR ELECTROPLATING MACHINE.

armature winding being independent, and the machine so made that they may be connected in series or parallel, giving either the sum of their voltages with the current of one, or the voltage of one and the current of both. Five or more volts per commutator is the ordinary practice, depending upon con-



ditions. Seven and one-half, 16 and 30 K. W. machines have been made of this type.

Fig. 2 shows the latest two-pole type, of which  $\frac{3}{4}$  and  $1\frac{1}{2}$  K. W. machines have been made.

Fig. 3 shows a unipolar or continuous-pole machine, designed for 2 volts and 6,000 amperes, and from which was drawn when tested 9,000 amperes.

Eddy machines for electrolytic work have been made up to a capacity of 150 K. W., and will be made in future by the Eddy Mfg. Corporation, Windsor, Conn.

### PERSONAL.

PROF. F. HABER, of the Institute of Technology, of Karlsruhe, Germany, and Prof. R. S. Hutton, of Owens College, Manchester, England, are visiting this country to study the development of the electrochemical industries in the United States. Both gentlemen will attend the meeting of the American Electrochemical Society, at Niagara. Prof. Haber is the official delegate of the German Bunsen Society (which is the new name of the German Electrochemical Society). Prof. Haber is the author of an excellent German treatise on industrial electrochemistry on a theoretical basis.

### INDUSTRIAL NOTES.

THE UNITED BARIUM CO. are erecting a two-story brick storage warehouse, 60 by 120 feet.

THE NORTON EMERY WHEEL CO. are about to install two additional furnaces for the bauxite fusion process, increasing their capacity 50 per cent.

A. J. Rossi has been running his electric furnaces during July and August, producing ferro-titanium alloy for experimental use in casting car wheels. During September operations will be discontinued, awaiting the results of the experiments.

THE CARBORUNDUM CO. are extending their furnace room so as to increase its capacity 50 per cent. The new block of five furnaces will require an additional 1,000 horse-power, and will be ready for operation as soon as the power company can furnish the power.

THE ELECTRICAL LEAD REDUCTION CO. are designing reduction apparatus for the whole of their large cell room, which has heretofore contained only one-tenth of its cell capacity, and expect before the end of the year to be running full capacity at a greatly decreased cost of operation.

THE NIAGARA POWER CO. have their first ten units of 5,000 horse-power fully occupied, and several works are awaiting the opening of the new power house to enlarge their capacity. The first 10,000 horse-power of the new plant is being rapidly put in place, and October 10th is the date now set for turning on this current.

THE ACKER PROCESS CO. are erecting scrubbing towers to the north of their bleaching-powder plant, to absorb the residual chlorine. The gases from the lime chambers carry out 0.01 to 0.05 per cent. of chlorine, which at present escapes into the air, but will in future be completely absorbed by passing through the scrubbing towers, where it comes in contact with coke saturated with water.

THE ATMOSPHERIC PRODUCTS CO. are erecting a small, but handsome, red-brick two-story building, 50 by 120 feet, situated close to the upper works of the Pittsburg Reduction Co. The building is to be used as a machine shop, to wind the small choke coils which are required in such large numbers for the apparatus they use. The large 2,000 horse-power plant, which is in contemplation, and in which the apparatus to be built will be placed, will be located elsewhere, where a large plot of ground will afford room for further extensions.

THE PITTSBURG REDUCTION CO.'s lower works were shut down, July 24th, by a strike of 72 pot men, who struck for recognition of their union and employment of only union men. The statement in the daily press that the employees were "locked out" by the company was incorrect, since the night force vacated the premises without notice at 11 P. M. This is the first trouble between this company and their employees, as the liberal wages they have given for eight-hour shifts has heretofore obviated all excuse for strikes.

THE MANUFACTURE OF CARBON BISULPHIDE by electrochemical means is carried on by Edward R. Taylor at Penn Yan, N. Y., on a large scale. The plant is situated on a well-chosen source of water supply, and power is developed by two horizontal low-head turbines. Carbon bisulphide is produced by direct reaction between vapors of sulphur and carbon in an electrical furnace. The vapors combine, escape to the condensers and are there liquefied. This furnace, recently patented by Mr. Taylor, is an interesting and efficient one. The average output per twenty-four hours is 8,000 pounds, but as much as 11,000 pounds per twenty-four hours have been produced. Carbon bisulphide is used extensively as an insecticide and disinfectant for protection against weevil, rats, mice and other vermin.

ELECTROCHEMICAL LABORATORY MATERIAL.—Though the demand for electrochemical apparatus and material is of comparative recent origin, Eimer & Amend, the well-known chemical and chemical apparatus supply house of New York, have thoroughly equipped themselves to supply needs extending over practically the entire range of electrochemical analysis and testing. They have made a specialty of electric furnaces and analytical and testing electrochemical laboratory apparatus and materials, as well as of electrochemically-made metals. One branch to which they have devoted special attention is that dealing with calorimetry and high-temperature measurements, the latter being represented by a line of pyrometers and electric indicators. They are representatives for the United States of the leading foreign firms who deal in electrical and chemical apparatus and chemicals.

BARIUM HYDRATE AS A WATER PURIFIER.—Barium hydrate, which is now made electrochemically by the United Barium Co., Niagara Falls, N. Y., is used as a purifier and softener of boiler waters. Its former high cost has prevented its general use, but this company, by an electrochemical process, manufacture it in large quantities and so have reduced its cost. The chief claim made for it is the complete removal of sulphates, the worst scale former in water. The substances are not neutralized and left in the water, but are completely removed, leaving the water as pure as is desired. Dr. Dudley, chief chemist for the Pennsylvania Railroad; Bertram Blount, the well-known English chemical engineer, and Thorpe in his *Outlines of Industrial Chemistry*, a recognized authority on water purification, all unite in the opinion that barium hydrate offers the only solution for the problem of completely removing scale-forming compounds from water and predict its general use in that capacity.

### INTERNATIONAL CONGRESS FOR APPLIED CHEMISTRY.

The fifth International Congress for Applied Chemistry will be held in Berlin, Germany, June 2 to 8, 1903. Honorary president will be Prof. A. Winkler; president, Prof. O. N. Witt; treasurer, Dr. H. T. Boettinger (the president of the German Bunsen Society). There will be three general sessions, at which papers of general interest will be read. The principal work of the congress will, however, be done in the different special sections. There are 11 sections: section 10 being for electrochemistry and physical chemistry. Dr. G. Pulvermacher is secretary, with office at Marchstrasse 21, Charlottenburg.

## DIGEST OF U. S. PATENTS PRIOR TO JULY, 1902.

Compiled by Byrnes & Townsend, Patent Lawyers,  
National Union Building, Washington, D. C.

This digest of electrochemical United States patents, prior to July, 1902, will be essentially one by classes, that is to say, it will set out for comparison those devices which have the same object, or those methods which seek the same result. In each class the patents will be arranged chronologically. It is the intention to make this digest complete in the sense of covering every point which is touched upon in the original specification. The first class to be dealt with comprises the patents on the electrolysis of sodium chloride with mercury cathodes.

271,906. February 6, 1883; A. L. Nolf, Brussels, Belgium.

Gas-retort carbon anodes slowly revolved over a quiescent layer of mercury, 1 cm. deep, resting on horizontal sheet-iron bottom of closed vessel.

Electrolyte, sodium chloride maintained saturated by crystals in perforated receptacles.

Amalgam drawn off while still fluid and distilled for sodium, or for rich amalgam, or converted into caustic soda by warm water.

307,463. November 4, 1884; A. S. Hickley, Montreal, Can.

A secondary battery with carbon anode, mercury cathode, sodium chloride or potassium chloride electrolyte.

Amalgam is formed in charging, chlorine escaping; in discharging, amalgam acts as anode.

Cell provided with incomplete partition at end, whereby part of the mercury may be withdrawn to regulate battery, or all may be separated from electrolyte to stop action.

307,462. November 4, 1884; A. S. Hickley, Montreal, Can.

Improvement on above.

Mercury contained in superposed stone trays and contact made by immersed wire netting.

Wooden grate in upper part of each tray supports a small stool, which serves to support and space the tray next above.

Anode-broken carbon packed around and between trays, contact being made by carbon rods.

Electrolyte sodium chloride solution.

356,640. January 25, 1887; A. S. Hickley, Montreal, Can.

Cathode mercury in depression in cell.

Anode, a carbon block above the mercury; supplemental anodes of broken carbon surround the mercury-containing depression.

Continuous flow of sodium chloride solution through cell and saturation chamber.

To remove amalgam employs a sieve; the thick amalgam is pressed to remove surplus mercury and packed in air-tight vessels. Subsequently used in primary or secondary batteries.

501,783. July 18, 1893; E. Hermite, Paris, and A. Dubosc, Rouen, France.

Mercury flows down over inclined surface of amalgamated copper, in close proximity to parallel platinum anodes.

Passes into trough, where it is allowed to stratify under carbon disulphide. Richer amalgam drawn off into separate vessel, decomposed by water and mercury returned.

Applicable to any solution of an alkali or alkali-earth metal, as Na, K, NH<sub>4</sub>, Mg, Al.

In oxidizing, cell may form bases (with water), or any desired salt, as carbonates, by passing carbon dioxide through the water.

513,661. January 30, 1894; C. T. J. Vautin, London, Eng.

Finds that surface tension of mercury will prevent it from passing through perforations corresponding to 60-mesh sieve, if not subjected to shock and no considerable head.

Mesh of non-conducting material, as silk, perforated cellu-

loid or vulcanite, or enameled metal, placed horizontally. Anodes at side and provided with chlorine-collecting hoods.

Sodium amalgam transferred through the mercury and oxidized by supernatant water.

Also oblique arrangement, the mercury cathode being arranged in terraces.

Also vertical arrangement, perforated or slotted iron plate, covered with vulcanized rubber. Mercury retained in perforations by mesh as above.

518,135. April 10, 1894; H. Y. Castner, London, Eng.

Apparatus for carrying out process of U. S. Patent 528,322.

Cell having two anode compartments and one intermediate cathode compartment, is supported on two adjustable knife edges and rocked by eccentrics.

For  $\frac{1}{4}$ -inch depth of mercury the eccentrics have a pitch of about  $\frac{1}{4}$  inch.

525,555. September 4, 1894; A. Sinding-Larsen, Christiania, Norway.

Mercury caused to flow by paddles through annular channel, passing at one point beneath a rotating anode, which is in an offset from central compartment, and separated from annular trough by incomplete partitions, the mercury acting as a seal.

Annular trough filled with water and central chamber with offset for anode with sodium chloride solution.

Cathode connections to mercury.

528,153. October 30, 1894; T. Drake, Huddersfield, Eng.

Porous pot closely wrapped with amalgamated wire gauze or equivalent cathode.

Anodes of carbon cast in lead cover in pot.

Sodium chloride solution in pot and water outside, both circulated.

528,322. October 30, 1894; H. Y. Castner, London, Eng.

Mercury cathode circulated (by pump or stirrer with radial blades) between anode compartment, containing sodium chloride solution, and cathode compartment, containing water.

Supplemental cathode and electrical connections to reduce the required electromotive force.

546,348. September 17, 1895; W. A. Rosenbaum, Montclair, N. J.

Body of mercury in annular trough. Annular bell, divided by transverse partitions, forming alternate decomposition and oxidation compartments, rests in trough, mercury operating to seal compartments.

Sodium amalgam formed in decomposition cells, annular bell rotated and amalgam oxidized by water.

May rotate bell continuously or oscillate.

Separate anodes and cathodes in oxidation cell, anodes being close to surface of amalgam to facilitate oxidation.

Ribs to retain mercury quiescent.

546,353. September 17, 1895; A. Sinding-Larsen, Christiania, Norway.

Vertical annular chamber contains rotating ring of amalgamated, tinned sheet iron, which, at lower portion, passes through the mercury cathode.

Center forms anode chamber, containing also feeding chamber.

Amalgam, as formed, is carried down through mercury by a small amalgamated roller, taken up by revolving ring and exposed to water in the annular chamber.

Automatic device for withdrawing caustic soda from latter at predetermined density.

Also a horizontal arrangement in which ring is conical, and amalgam is caused, by centrifugal action, to travel upward in a thin film.

[The digest of the patents of this class will be continued in the next issue.]

